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42.	Charles H. Townsend	1912–1913	Denver, Colo.

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[1] A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

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64.	E. L. Wickliff	1934–1935	Montreal, P. Q.
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68.	Fred J. Foster	1938–1939	Asheville, N. C.
69.	T. H. Langlois	1939–1940	San Francisco, Calif.
70.	James Brown	1940–1941	Toronto, Ont.
71.	John Van Oosten	1941–1942	St. Louis, Mo.
72.	John Van Oosten	1942–1943	(No meeting)[2]
73.	John Van Oosten	1943–1944	(No meeting)[3]
74.	John Van Oosten	1944–1945	(No meeting)[3]
75.	John Van Oosten	1945–1946	(No meeting)[3]
76.	Joseph R. Hogan	1946–1947	St. Paul, Minn.
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78.	Seth Gordon	1948–1949	Atlantic City, N. J.
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80.	Albert S. Hazzard	1950–1951	Memphis, Tenn.
81.	W. J. K. Harkness	1951–1952	Rochester, N. Y.
82.	Ralph Hile	1952–1953	Dallas, Texas
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85.	George A. Sprecher	1955–1956	Augusta, Ga.
86.	Clarence F. Pautzke	1956–1957	Toronto, Ont.
87.	H. S. Swingle	1957–1958	Las Vegas, Nevada

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[2] The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

[3] No annual meeting scheduled because of the war.

In Memoriam

James A. DeJean, Port Barre, Louisiana

Karl C. Kulle, Suffield, Connecticut

T. S. Palmer, Washington, D. C.

S. L. Hora, Calcutta, India

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Part 1

Papers

RETURN OF SILVER SALMON, *ONCORHYNCHUS KISUTCH* (WALBAUM) TO POINT OF RELEASE

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AND

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Arcata, California

ABSTRACT

Silver salmon, *Oncorhynchus kisutch* (Walbaum), of the 1950 brood year were reared at the Soos Creek Hatchery, State of Washington Department of Fisheries, until January 19, 1952. On that date, approximately 72,000 fingerlings were divided between the State of Washington salmon hatchery on Issaquah Creek and the ponds of the School of Fisheries, University of Washington. After two months of orientation, the two lots of fish were released to migrate to sea on March 18 and 19, 1952.

The movement of the fish in the sea were followed by noting the return of the marked fish to the sport and commercial fisheries.

Adult salmon returning during the winter of 1953-1954 were examined for marks. None of the marked fish returned to Soos Creek, their native stream. Those fish released at the School of Fisheries returned up the ladder to the rearing ponds and those released at Issaquah migrated to the head of the watershed, returning to the area of release.

INTRODUCTION

The fish-cultural stations of the State of Washington Department of Fisheries at Minter Creek, Soos Creek, and Issaquah Creek have well-established runs of silver salmon *(Oncorhynchus kisutch* Walbaum) returning to a natural environment. With the completion of the Fisheries Center in 1950 to house the School of Fisheries, facilities became available for rearing and releasing salmon, with the possibility of establishing a return migration of the adult fish to an artificial salmon habitat (Van Cleve, 1952).

The combination of facilities of the State of Washington Department of Fisheries and the School of Fisheries, University of Washington, presents a unique opportunity for the study of multiple choice responses by migrating salmonoid fishes. The four stations, all located in the southern Puget Sound area, with two of them, the University of Washington and the Issaquah stations, on a single drainage system (Fig. 1), provide observation points in close proximity for evaluating problems of migration, survival, time and conditions of spawning, and management techniques.

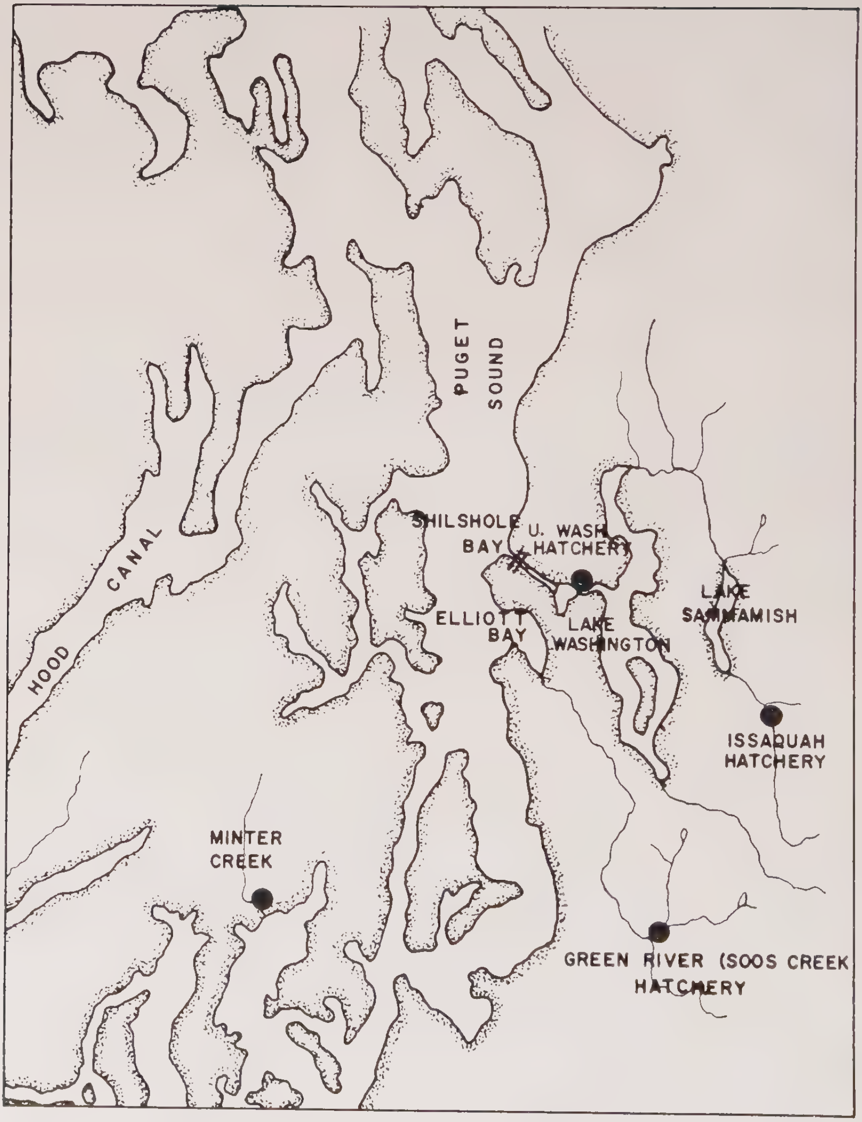
PUGET SOUND
HOOD CANAL
SHILSHOLE BAY
U. WASH. HATCHERY
LAKE SAMMAMISH
ELLIOTT BAY
LAKE WASHINGTON
ISSAQUAH HATCHERY
MINTER CREEK
GREEN RIVER (SOOS CREEK HATCHERY

FIGURE 1.—Map of southern Puget Sound showing some of the salmon hatcheries used in studying migration of salmon.

The present study deals with the release and possible return of about 72,000 silver salmon fingerlings of the 1950 brood year held at the Issaquah and the University of Washington stations and marked by the removal of a ventral fin. The fish were divided into two lots and released simultaneously at the two stations. After a feeding period in Puget Sound and/or in the sea the fish returned to spawn. Runs at the four stations were watched carefully for marked fish. Conditions stimulating final migration in the return were studied by Allen (1956).

SOURCE AND DOWNSTREAM MIGRATION OF FINGERLING SALMON

During the 1950 brood year, a total of 16,076 adult silver salmon returned to the Soos Creek Hatchery racks (Washington Department of Fisheries, 1956). A part of this run was spawned at the hatchery to provide eggs for rearing and stocking programs.

A portion of the silver salmon fingerlings from these eggs were reared in the ponds at the Soos Creek station until January 19, 1952, when approximately 72,000 were divided into two lots. One lot was transferred to the Issaquah Hatchery of the State of Washington Department of Fisheries and the other to the University of Washington School of Fisheries Hatchery on Lake Union (Fig. 1).

The two lots of fish were marked during January and February, 1952. Those transferred to the Issaquah Hatchery were marked by removal of the right ventral (RV) fin and those at the School of Fisheries by removal of the left ventral (LV) fin. The marked fish were released on March 18 and 19, 1952, to start their seaward migration.

Samples from the two groups of fish were measured at the time of release. Fish with the left ventral (LV) mark from the School of Fisheries ponds were slightly larger than those with the right ventral (RV) mark released at the Issaquah station (Table 1).

TABLE 1.—*Comparison of length and weight of silver salmon fingerlings at time of release March 18 and 19, 1952.*

Point of release	Mark[1]	Number released	Average length (millimeters)		Average weight per fish (grams)	Number of fish per pound
			Fork	Standard		
Issaquah Creek	RV	36,833	93.6	87.0	10.49	43.3
Lake Union	LV	34,405	106.4	100.3	14.82	30.6
		71,238				

[1] RV = right ventral; LV = left ventral.

The downstream migration of silver salmon fingerlings has been studied for many years by the Washington Department of Fisheries. The data were summarized by Salo (1955), who observed that the wild silver salmon fingerlings migrate from Minter Creek from April to June, with the peak of the migration occurring in early May. The fish migrate out of Minter Creek at one-plus years of age when they are about 100 millimeters standard length.

Silver salmon migrating from Waddell Creek, (Shapovalov and Taft, 1954) leave the stream in greatest numbers during April and May when they are about 115 millimeters fork length.

The marked fingerling silver salmon released in Issaquah Creek, after two months of orientation in the ponds at the Issaquah Hatchery, moved down the stream into Lake Sammamish, then down the Sammamish River into Lake Washington, and from there into Lake Union where the remainder of the lot, which had been transferred from Soos Creek to the ponds at the University, were released. After the short trip (5 miles) through Lake Union and through the locks of the Ship Canal, the young fish entered Puget Sound at Shilshole Bay (Fig. 1).

OCEAN MIGRATION AND FISHING CATCH OF MARKED SALMON

Silver salmon during their feeding period in the sea are subjected to very intense sport and commercial fisheries. Salmon marked by removal of the left ventral or right ventral fins were reported as being caught by the sport and commercial fishermen from July 1952 to February 1954. The fisheries along the west coast cooperating in the recovery and reporting of marked fish together with the number of right and left ventral marked fish recovered are listed in Table 2.

TABLE 2.—*Recovery in the fisheries and return to the hatcheries of marked silver salmon released into the Lake Washington drainage system March 18 and 19, 1952*

Reporting fishery	Release station and fin mark		Number of fish sampled
	Univ. of Washington (LV)	Issaquah Hatchery (RV)	
Bush Point reef net, 1952	5	5	6,745
Sport fishery—Puget Sound			
Sampling	5	7	7,784
Post Card	12	31	—
Alaska troll fishery	4	1	26,315
British Columbia troll			
West Coast Vancouver Island	23	11	37,170
Strait of Georgia	2	2	30,834
Washington troll fishery	91	84	177,594
Sport fishery—Westport	2	1	1,559
Cape Flattery purse seine	0	1	1,263
Bush Point reef net, 1953	1	2	688
Admirality Inlet purse seine	11	9	2,319
Seattle gill net	39	32	7,233
Total marks recovered by the fishery	195	186	
Marked fish recovered by the hatcheries	124	70	

Of the 381 silver salmon marked by removal of the right or left ventral fins captured in the fisheries, the majority were fish that had migrated out of Puget Sound into the Pacific Ocean. Some of the marked fish, however, apparently remained in Puget Sound during their marine feeding period. These fish grew much more slowly than those that migrated to the open sea.

The exact number of fish with right and left ventral marks taken in the sport and commercial fisheries could not be determined. It was possible, however, to estimate the number of marked fish caught from the following ratio:

$$\frac{\text{Number of marks recovered}}{\text{Number of fish examined}} = \frac{X}{\text{Total estimated catch}}$$

in which X is the calculated contribution of the marked fish to the fishery. For a few of the fisheries, indirect methods were employed in estimating the contribution of the marked fish. However, the major portion of returns, as calculated by Allen (1956), was from a sample of 346,000 fish from landings estimated to be about 2,600,000 fish.

Of the 34,405 fish with left ventral marks that were released from the ponds of the University, the recorded catch was 195 fish and the calculated catch was 1,150 fish, or 3.34 percent of the fish released.

The recorded catch of silver salmon marked by removal of the right ventral fin and released from the Issaquah Hatchery was 186 fish. Of the 36,833 fingerlings released the calculated catch was 978 fish or 2.66 percent of the fingerlings planted.

RETURN MIGRATION OF MARKED SALMON

Silver salmon usually return from the sea to spawn as mature fish during their third year of life. Nearly all of the streams tributary to Puget Sound have runs of silver salmon that enter them during the late fall and winter months. The four fish-cultural stations referred to in this study have facilities for collecting the entire runs of fish entering the streams, thus making it possible to inspect the fish for marks.

During the fall and winter of 1953-1954, 12,362 silver salmon returned to Soos Creek (Washington Department of Fisheries, 1956). Fish were collected between the two traps, (Fig. 2) where they were examined for marks, spawned or released upstream. Although the 71,238 silver salmon which were marked and released into the Lake Washington drainage system were native to Soos Creek and were incubated and reared in Soos Creek water for the first year of their lives, none of these marked fish returned to that creek.

To enter Issaquah Creek the silver salmon must migrate 35 miles through the Lake Washington drainage system, passing the pond entrance at the University on the way. A total of 2,285 adult silver salmon entered the

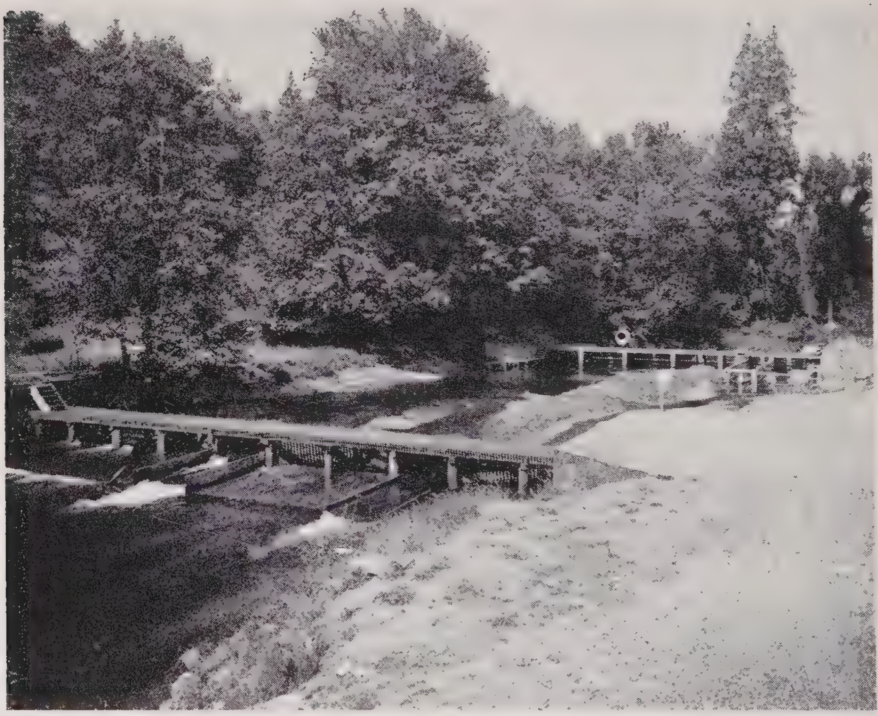

FIGURE 2.—Salmon collecting area of the Soos Creek Hatchery. Mature salmon are collected between the two racks until they can be examined by personnel of the State of Washington Department of Fisheries. *(Washington Department of Fisheries photo.)*

Issaquah Creek trap (Fig. 3) during the fall and winter of 1953-1954. Among the native silver salmon returning were 70 fish marked by a missing right ventral fin and one fish, a male, with the left ventral fin missing. The 70 marked fish represented a return to the hatchery racks of 0.19 percent of the marked fingerling fish released.

Survival of fish with the left ventral mark returning up the ladder (Fig. 4) and entering the ponds at the University exceeded that of fish with the right ventral mark returning to Issaquah Creek. A total of 124 fish, representing 0.36 percent of the fingerlings released, entered the University pond.

No fish with the right ventral mark strayed into the University pond although the fish migrating up through the Lake Washington drainage to Issaquah Creek passed within a few yards of the ladder entrance.

A check of the 1,680 spawning silver salmon entering the traps on Minter Creek showed marked salmon of releases from that station but none of the fish with right or left ventral marks released into Issaquah Creek or Lake Union.

TIME AND CONDITIONS OF SPAWNING MIGRATIONS

Adult silver salmon enter Soos Creek on their spawning migrations during October, November and December. The peak of the run usually occurs during the last two weeks in November. In 1953 the peak of the spawning run occurred from November 20 to December 10. The average water temperature for Soos Creek was 47.0° F. for November and the average stream flow was 108 c.f.s. (Table 3).

At Issaquah Creek, although a few fish entered the stream in October, the great majority of the fish entered the trap and were counted during November and the first two weeks in December. The average November and December temperatures in the creek were 50.4° F. and 48° F., the average stream flows 98.7 and 164 c.f.s. respectively for the two months.

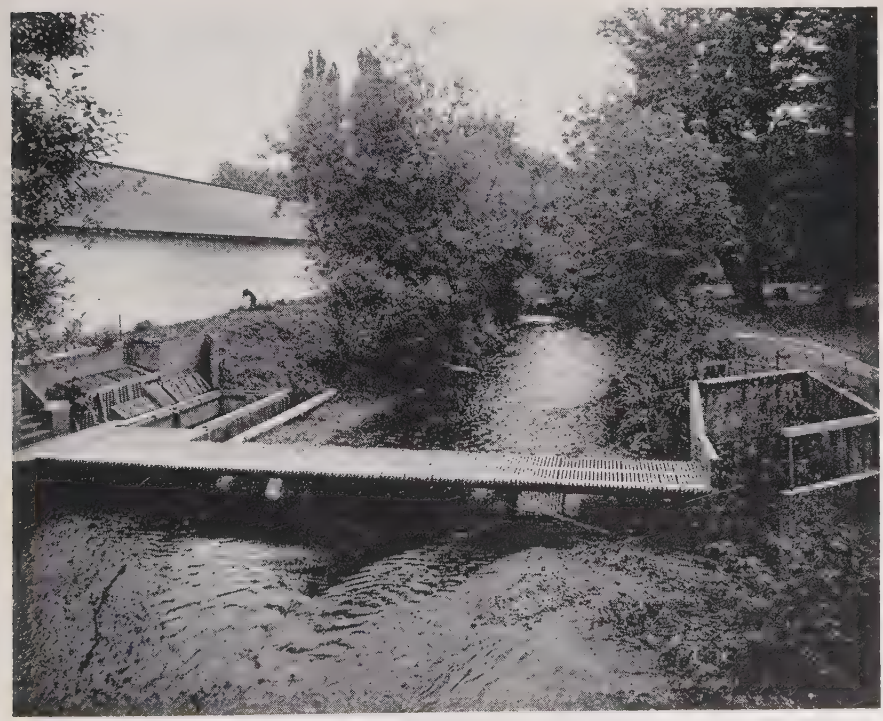

FIGURE 3.—Salmon trap across Issaquah Creek at the Issaquah Hatchery. The collecting box on the left is used to hold migrating silver salmon.
(Washington Department of Fisheries photo)

TABLE 3.—*Monthly average discharge and temperatures (F°) of the Soos Creek, Issaquah Creek, and University hatchery water supplies.*

	1953			1954								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Soos Creek												
Discharge (c.f.s.)[1]	42.5	108	296	340	241	157	132	71.7	57.1	47.8	35.2	37.8
Average temperature	52.4	47.0	45.1	41.6	43.0	42.9	48.9	52.6	53.6	55.7	55.3	54.9
Issaquah Creek												
Discharge (c.f.s.)[1]	28.0	98.7	164	157	137	75.7	72.1	33.7	48.5	38.0	23.3	29.9
Average temperature	53.7	50.4	48.0	42.2	44.4	44.2	47.0	53.0	53.6	57.0	56.8	55.6
School of Fisheries												
Discharge (c.f.s.)	1.2	1.2	1.2	1.2	.5	.5	.5	.5	.3	.3	.3	.3
Average temperature	56.7	52.5	48.5	45.4	46.4	48.2	50.0	54.8	56.8	61.9	56.8	61.4

[1] Data from U. S. Geological Survey (1956).

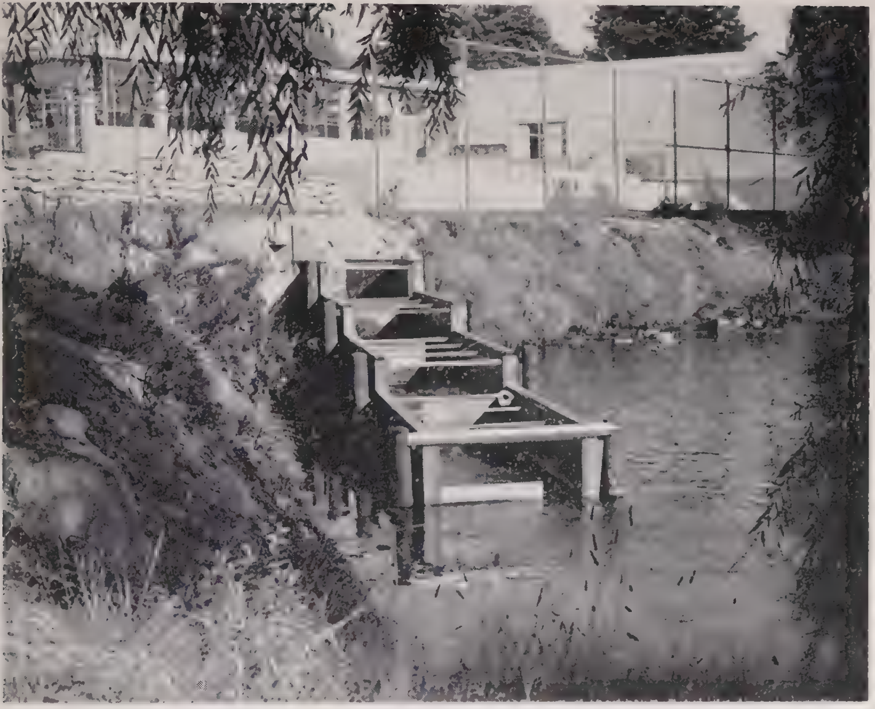

FIGURE 4.—Fish ladder at the University of Washington leading from the small bay which joins Lake Union. Salmon move up the ladder on rainy nights. *(Photo by J. O. Sneddon, University of Washington.)*

There are three water supply sources for the School of Fisheries: (1) water from a well on the campus, (2) city water and (3), the major source, which is water pumped from the Lake Washington Ship Canal at its entrance into Lake Union. Discharge water from the various laboratories in the Fisheries Center is collected and added to the lake water supply to provide a flow of about 1.2 c.f.s. down the small fish ladder (Fig. 4) up which the fish must swim to reach the collecting pond. This small flow produces a maximum current velocity of 0.85 feet per second 4 feet from the end of the ladder and only 0.25 feet per second where the discharge from the ladder joins the water of the Lake Washington Ship Canal.

The fishway which the fish ascend to enter the collecting pond has 8 pools with jumps between pools varying from 9 to 11 inches in height. The openings between the pools are 1 foot wide and the water spilling over is about 6 inches deep. The small, uniform flow of water discharged down the ladder does not cool to below 50° F. until December (Table 3).

Silver salmon enter the fishway mostly at night (Allen, 1956). The peaks in the run occur during rainstorms. During the 1953-1954 run, the first silver salmon entered the pond November 5, 1953, with a water temperature of 53° F. The peak of the run, however, did not ascend the ladder until the first week in January when the discharge water from the ladder had fallen to 47° F. or less.

SUMMARY AND CONCLUSIONS

Silver salmon transferred as fingerlings, after a year of rearing, did not return to their native stream, but to the point of release. The amount of straying in the transplanted fish (1 to 194 correct choices) was much less than Taft and Shapovalov (1954) found for two California streams,

> . . . during the entire period 314 (85.1 percent) of the fish marked at Waddell Creek returned there and 55 (14.9 percent) strayed to Scott Creek. Of those marked at Scott Creek 41 (73.2 percent) returned there and 15 (26.8 percent) strayed to Waddell Creek.

Silver salmon returned successfully to an artificial environment even though they had to ascend a fish ladder in which water flow is small (1.2 c. f. s.) to gain entrance to the concrete retaining pool. The fish did not move into the collecting traps in numbers until the temperatures dropped to below 50° F. A delay in attaining suitable water temperature of a month or six weeks past the normal spawning season seems not to interfere with the run.

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EXPERIMENTAL CONTROL OF CARP REPRODUCTION THROUGH WATER DRAWDOWNS IN FORT RANDALL RESERVOIR, SOUTH DAKOTA

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ABSTRACT

Water drawdowns of 1½ to 2 feet were effected at Fort Randall Reservoir immediately following periods of major carp spawning in 1955, 1956, and 1957. Eggs thus exposed were killed. Predictions of the time of spawning were based on gonadal conditions of mature fish, water temperature and weather forecasts. Major spawning occurred in shallow (less than 1 foot deep) flats during periods of warm, calm weather when open-water temperature first reached 62-68° F. Effectiveness of the drawdowns in limiting carp reproduction was judged by the size of the age class produced each year in comparison to a previous year and to other species sampled by the same methods of spot-poisoning, shoreline seining, gill netting and frame netting. Size of the age class of carp established each year was relatively small. It is concluded that the planned drawdowns were primarily responsible for poor reproduction.

INTRODUCTION

Control of carp *(Cyprinus carpio)* has been a serious problem since the species became a nuisance soon after its introduction into the United States in the 1870's. Control efforts have been directed primarily at adult fish by various means of trapping and netting. More recently, chemical eradication of entire fish populations has been undertaken as a means of ridding a water area of carp. Success of these methods has depended upon a variety of conditions, but primarily on the ability to exert maximum effort on small water areas. In large water areas heavy landings of carp often have been referred to as control, though more correct terminology would be cropping or harvest of surplus.

Attacking carp at the vulnerable egg stage has received considerable mention but little experimentation. Perhaps the most notable literature pertaining to the potentiality for control at this stage are in the voluminous writings on carp culture. Europeans have made a science of carp culture, and their writings such as those of Schaeperclaus (1933) outline vulnerable stages in the reproductive cycle. Richardson (1910) outlines remedial methods for poor reproductive success, the antithesis of which would be possible control methods. In practically all literature on carp culture, proper water level at spawning time is stressed. Tarzwell (1941) apparently was one of the first to point out the possibility of controlling carp in large reservoirs by manipulation of water level. He noted a relatively small hatch of carp in Pickwick Reservoir, Tennessee, and suggested that it was due to water level fluctuation at spawning time. However, the inherent difficulties in accomplishing timely drawdowns in most lakes and reservoirs has practically eliminated necessary experimentation in large water areas to determine the practical value of the technique. These difficulties were overcome at Fort Randall Reservoir in 1955, 1956 and 1957, through excellent cooperation of the Omaha office of the U. S. Army, Corps of Engineers.

Fort Randall Reservoir is a multiple-purpose impoundment on the Missouri River in South Dakota. It has a maximum size of 118,000 surface acres. During the springs of 1955, 1956 and 1957, its area approximated 70,000 to 85,000 surface acres, with an average width of about 1¼ miles, length of 85 miles, and maximum depth of about 100 feet. In the first year of impoundment, 1953, there was a tremendous production of carp as well as of most other species present in the Missouri River.[1] In 1954, however, reproduction of carp was practically nil, as indicated by small-mesh seine hauls and spot-poisoning in 1954 and gill and frame netting in subsequent years.[2] [3] Failure of the 1954 carp hatch was believed to have been caused by a severe drawdown of about 9 feet, starting late in June and lasting several weeks. In subsequent years, intensive efforts were made to determine the exact period of spawning and to effect drawdowns of 1½-2 feet immediately following heavy spawning, thus exposing and killing the eggs.

METHODS

The Corps of Engineers required from 1 to 9 days advance notice of desired drawdowns, depending upon operational schedules for the entire Missouri River reservoir system. Thus, it was necessary to predict major periods of spawning up to 9 days in advance. To accomplish this, samples of fish were obtained and inspected for gonadal conditions, water temperatures were recorded and plotted, and all available weather forecasts were obtained.

Fish were caught by use of nets and an electric shocker, with the shocker producing most of the fish when used in bays and at the mouths of creeks. Netting gear included frame (modified fyke) nets with 75-foot leads, and 250-foot experimental (50-foot sections of 2-, 2½-, 3-, 3½- and 4-inch mesh, stretch measure) nylon gill nets. Electric shocking equipment consisted of two pole-type electrodes connected by 30-foot cords to a 230-volt, AC portable generator.

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[1] Shields, James T. 1955. Report of fisheries investigations during the second year of impoundment of Fort Randall Reservoir, South Dakota, 1954. D-J Project F-1-R-4, 100 pp. mimeo.

[2] Shields, James T. 1956. Report of fisheries investigations during the third year of impoundment of Fort Randall Reservoir, South Dakota, 1955. D-J Project F-1-R-5, 91 pp. mimeo.

[3] Shields, James T. 1957. Report of fisheries investigations during the fourth year of impoundment of Fort Randall Reservoir, South Dakota, 1956. D-J Project F-1-R-6, 60 pp. mimeo.

Gonadal condition of fish was determined nearly every day, beginning when water temperature was 50-55° F. and was continued through the spawning periods. Subsequent data were obtained periodically throughout the summers while carrying on test netting activities. Specimens were collected throughout the reservoir in 1955, but primarily from a centrally located area in 1956 and 1957, because it had been determined that spawning occurred at about the same time in most of the reservoir.

Condition of testes and ovaries of mature carp was classified as green, near-ripe, ripe or spent. Fish were considered green when their organs were in a rather hardened state. Near-ripe was used to classify fish with enlarged and softening organs which contained eggs (or milt) extrudable with some difficulty by "stripping" the fish. Carp classified as ripe were readily stripped of eggs or milt with slight pressure. Spent females contained flabby ovaries with few or no eggs, and spent males possessed soft, flabby testes with reddish or blood-shot coloration.

Water temperature was recorded daily in shallow, protected areas and in open-water areas.

Continuous observations were made in likely spawning areas to determine when and where carp were spawning. The method found most exact was to wade in shallow, grassy areas and inspect for eggs attached to grass, weeds and sticks. When eggs were located, markers were set out and notations made of the depth and probable time of deposition.

Shoreline seining (and spot-poisoning in 1954 and 1955) was carried out weekly or bi-weekly throughout the summers to determine success of reproduction. A 40 by 6-foot, ¼-inch-mesh bag seine was used in seining, and Fish Tox was used in spot-poisoning. Seining was done in shallow portions (up to 4 feet deep) of bays and open water areas throughout the reservoir. Acreage seined was determined by measuring the distance between the ends of the seine, and the distance the seine was pulled on each haul. An average haul covered about 1500 square feet. Spot-poisoning of seven areas was accomplished in 1954 (4 areas) and 1955 (3 areas). These areas, both bays and open water areas, varied in size from ⅛ to 4½ surface acres and had maximum depths of 5 to 25 feet. Enough Fish Tox was used to effect concentrations of 1.0 to 4.5 ppm., depending upon water temperature and observed results. Subsequent to 1955, poisoning was discontinued since the results were poor and the unit of effort high in comparison to seining results and effort.

CARP REPRODUCTION AND DRAWDOWNS

Samples of carp measured and inspected for sexual development ranged from 3,584 in 1955 to 1,152 in 1957 (Table 1). The 1953 age class dominated the catch each year, however, so that the catch of adult females increased from 110 in 1955 to 269 in 1956 and 416 in 1957. Gonadal development of adult females was found to be the best indicator of time of spawning. Adult males usually ripened before females, and sometimes were found to be partially spawned during and after the major spawning period. Age and growth analyses during the three years[1 2 3] indicate that males matured at a rate of about 15 percent at Age I, 80 percent at Age II, 90 percent at Age III, and 100 percent at Age IV and older. Females matured at a rate of about 0 percent at Age I, 15 percent at Age II, 30 percent at Age III, 90 percent at Age IV, and 100 percent at Age V and

TABLE 1.—*Sexual development of carp by numbers and periods, Fort Randall Reservoir, 1955 - 1957.*

Date	Open-water temperature (degrees F.)	Number							
		Males				Females			
		Green	Near-ripe	Ripe	Spent	Green	Near-ripe	Ripe	Spent
1955									
5/1–7	51–55	5	6						
5/8–14	56–59	30	17						
5/15–21	60–66	107	87	27		15		14	
5/22-28	66–63	89	98	22		11	1	5	
5/29–6/4	63–68	41	72	35	25	3	4	2	
6/5–11	67–64	17	70	102	16			5	
6/12-18	64–68	18	26	40	5		5	2	
6/19-25	69–70	35	9	2	2	3	6		
6/26–7/2	70–78	16	5	1	6	1	1		1
7/3–8/27	77–82	106			133	6	4	2	19[1]
1956									
5/6–25	49–62	36	2			10			
5/26–6/2	62–65	35	43	9		23	3	1	
6/3–7	67–68	29	90	51		10	59		
6/8–14	69–76		22	120	6	6	34	8	13
6/26–28	76–76	7	8	1	43	6	1		28
7/7–9/6	76–79	21	1	1	78	12	2		53[1]
1957									
5/24–26	57–60	25	50	22		4	10		
5/27	59	37	23	8		21	12		
5/29	62	10	7	7	17[2]	28	16		31[2]
5/30	64		4	4	31	3	11	4	7
5/31	61		1	22	61		10	10	34
6/1–8	61–67			81[3]	86		12	23	40
7/23–8/22	77–83	10		1	48	3			59[1]

[1] Some fish absorbing eggs.

[2] Fish smaller than reservoir fish; believed to be from a small lake on a tributary stream.

[3] Some fish partially spawned.

older. There were variations from these percentages in some years due to small samples and differences in rate of growth.

Progressive gonadal development of carp served as a good indicator for predicting the period of major spawning. Temperature apparently was the primary stimulus to gonadal development and thus could be used as a means for long-range prediction. However, the factors of weather and water level were extremely important and actually regulated the time of spawning once the fish had reached a near-ripe or ripe condition and open water temperatures were between 55 - 65° F. Rapidly rising water level which inundated shallow vegetated areas was a definite inducement in that it provided ideal spawning habitat. Warm, sunny, calm weather was the trigger mechanism after other requirements were met. After open water temperature had risen above 62° F. (shallow protected areas were much warmer) and adequate habitat was available, spawning could be expected when proper weather prevailed. The length and intensity of the spawning period was in direct relation to the number of successive days of ideal weather.

In 1955, first spawning activity was noted May 21 when freshly-spawned eggs were located in grassy areas less than 1 foot deep. Open water temperature was 66° F. (Fig. 1), and shallow water temperature varied from 62 - 77° F. over a 24-hour period. The period May 20 - 23 was the first sunny, relatively calm period since water temperature had exceeded 60° F. Spawning was light during this period. On May 23, the weather became cold and rainy and surface temperature decreased to 63° F. by May 28. No spawning activity was noted from May 23 until June 1, when surface water warmed to 67° F. From June 1 to June 7, the weather was generally sunny and calm, and heavy spawning took place. Rising water (Fig. 2) had inundated many shallow grassy areas.

On June 8, a requested drawdown began and lasted through June 13, lowering the water level 1½ feet. This drawdown had been requested on May 31, giving the Corps of Engineers a necessary 9 days notice. The request was based on conditions of the fish and weather forecasts which indicated spawning would take place the first week in June.

All freshly spawned eggs located were in areas less than 1 foot deep. Receding water exposed all areas used for spawning during the period June 4 - 11, thus exposing and killing the great majority of eggs spawned. A small amount of spawning occurring June 1 - 3 and May 20 - 23 was not affected by the drawdown. Eggs collected from spawning areas and placed in jars (which were moved daily to keep them inundated) hatched in 6 - 8 days. Dried eggs were observed in the exposed spawning areas still attached to grass, weeds and sticks.

A second drawdown was effected June 22 - 27 following a second period of ideal carp spawning weather. However, there were no indications that spawning actually took place.

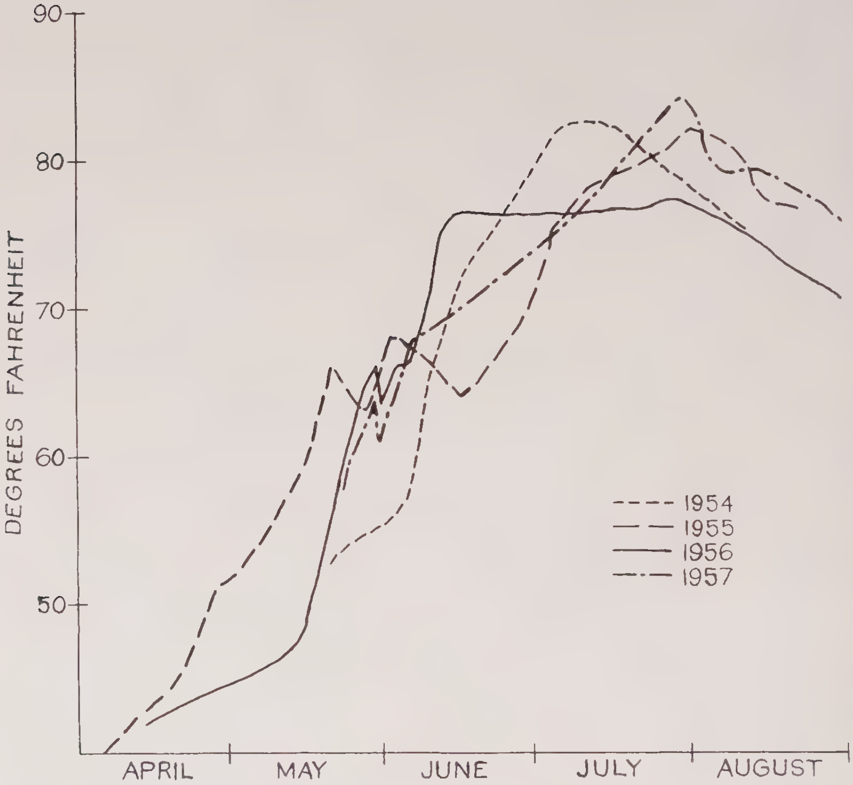

FIGURE 1.—Surface water temperature of Fort Randall Reservoir, April - August, 1954-1957.

In 1956, carp began ripening May 26 to June 2, when water temperature increased from 62 to 65° F. Spawning probably would have occurred June 3 - 6 had not cool, cloudy and windy weather prevailed. Beginning June 7, the weather became calm and hot, and water warmed to 76° F. by June 14. Carp responded and most spawning was completed by June 14. During the period June 12 - 15, a requested drawdown (only 1 day notice was required) was effected, lowering the level 1½ feet. This was sufficient to expose the shallow areas used for spawning.

There was little or no vegetation inundated in 1956 at the time of spawning due to higher water levels earlier in the year. Thus, eggs were difficult to locate even in areas where fish were observed spawning. The few eggs located were attached to coarse debris matted on the bottom.

In 1957, spawning took place at slightly lower open-water temperature than in previous years. Carp were beginning to ripen at a temperature of 58° F. on May 24, the first day that samples were obtained. There was little change in the degree of ripeness until May 28 or 29. Beginning May 27, the weather became unusually warm and calm and water temperature increased from 59° F. to 64° F. by May 31. Shallow areas warmed to 72° F. in the afternoons. Rising water had inundated large expanses of shallow,

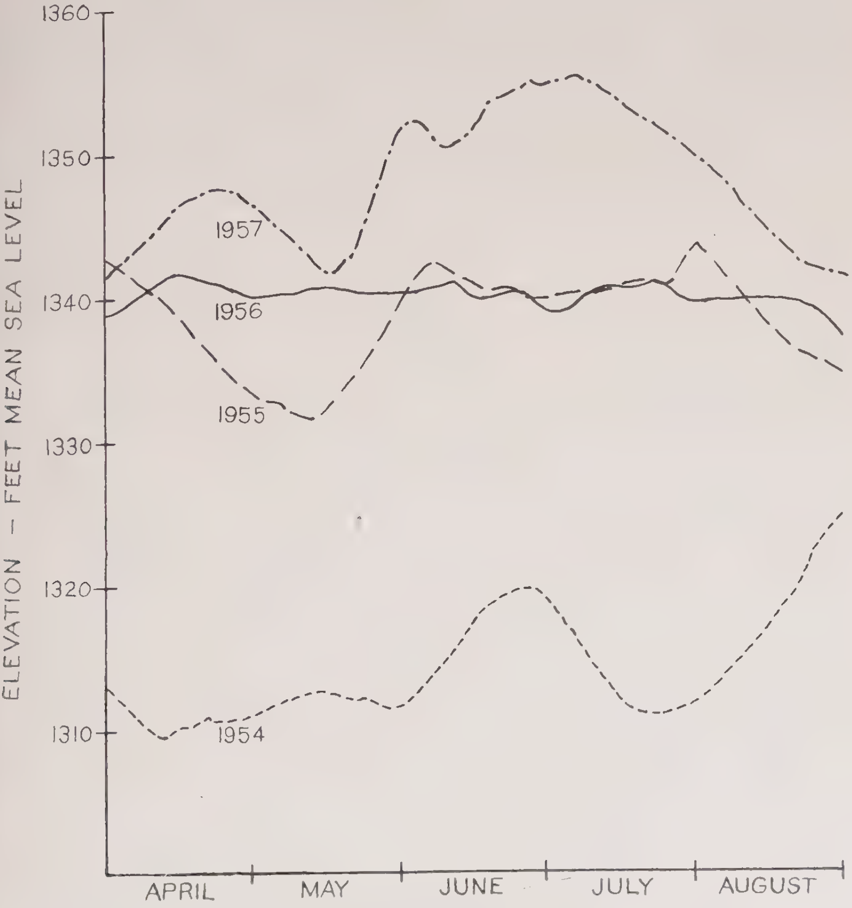

Figure 2.—Water level of Fort Randall Reservoir, April - August, 1954-1957.

grassy habitat. Carp responded to these ideal conditions with heavy spawning May 28 - 30. Heavy winds on May 31 caused a water turnover and a 3° F. decrease in open-water temperature. Following this, the weather again was ideal for spawning through June 4. Again the fish responded, though in decreased quantities. It was estimated that two-thirds of the spawning occurred May 28 - 30, and one-third from June 1 - 4.

Water drawdowns necessary to expose eggs spawned May 28 - 31 were impossible, due to heavy runoff throughout the Missouri River Basin. The earliest possible date a drawdown could be initiated was June 5, and on that date releases began which effected a 1½ foot drawdown by June 8. All areas used for spawning subsequent to June 1 were exposed and dried eggs were numerous. Those eggs spawned May 28-30 began hatching June 2 and were completely hatched by June 4. Tiny fry were abundant in the shallows, and a few of these were stranded in pockets created by receding water. However, swarms of fry were observed June 8, apparently having survived the physical effects of the drawdown.

Results of the unplanned drawdown in 1954 and the planned drawdowns in 1955, 1956 and 1957 can be judged best by the resultant year class of carp produced in each of these years. Catches of young-of-the-year fishes are tabulated in Table 2. In only two of the years, 1955 and 1957, were significant numbers of young carp taken. In each of these years all but a few of the carp were caught in the upstream area of the reservoir where river-like conditions prevailed and effectiveness of drawdowns was minimal. Several other species were taken in relatively large numbers each year, indicating good reproduction by those species as well as effectiveness of sampling methods. Similar sampling methods used in Gavins Point Reservoir (a downstream impoundment of 33,000 surface acres) resulted in a catch of 472 carp (0.60 acre sampled) in 1955, and 1,951 carp (4.56 acres sampled) in 1956[4] [5].

Further evidence of poor reproduction of carp in the years 1954, 1955 and 1956, are available from age and growth analyses and intensive netting studies.[1] [2] [3] Age and growth studies of 739 carp supplemented by length-frequency distribution of 5,126 carp during the years 1954, 1955 and 1956 indicate the 1953 age class comprised 90, 91 and 85 percent of the catch by frame and gill nets in the years 1954, 1955 and 1956, respectively. The 1954 age class comprised 3 percent of the catch in 1955 and 6 percent in 1956. The 1955 year class comprised only 4 percent of the catch in 1956. Average number of carp per 24-hour frame net set was 67, 15 and 6 in 1954, 1955 and 1956, respectively. Average catch of all species was 100,

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[4] Shields, James T. 1956. Test netting, seining and poisoning, Fort Randall and Gavins Point Reservoirs. D-J Project F-1-R-4, Job Number 3, 3 pp. mimeo.

[5] Shields, James T. 1957. Report of fisheries investigations during the second year of impoundment of Gavins Point Reservoir, South Dakota, 1956. D-J Project F-1-R-6, 34 pp. mimeo.

108 and 114 in the same respective years. Thus, it appears that poor carp reproduction since 1953 has caused a marked decline in population, while other species have more than compensated for this decrease.

The actual effectiveness of the drawdowns was somewhat different each year. In 1955, there was evidence of a small amount of successful reproduction prior to the major period of spawning. In addition, a fairly good hatch of carp occurred in the upstream section of the reservoir immediately following the first drawdown. In 1956, the small amount of successful reproduction apparently resulted from a few early spawners. In 1957, a large hatch of carp occurred during and just prior to the drawdown. Swarms of tiny fry were observed in the shallows at the time the drawdown was completed, proving they had survived the physical effects of the drawdown. Intensive seining one month later failed to produce a carp. Species spawning prior to and soon after carp reproduced well, suggesting that direct predation or the

TABLE 2.—*Catches of young-of-the-year fishes and minnows by seine and spot-poisoning, Fort Randall Reservoir, 1954 - 1957.*

Species[1]	Number			
	1954	1955	1956	1957
	(4.47 acres poisoned; 0.84 acre seined)	(0.50 acre poisoned; 1.53 acres seined)	(5.87 acres seined)	(5.16 acres seined)
Shortnose gar	—	1	—	3
Gizzard shad	1,119	2,122	928	17,793
Goldeye	11	3	—	—
Bigmouth buffalo	4	2	2	27
Smallmouth buffalo	12	8	1	6
River carpsucker	15	82	590	34
Common white sucker	—	—	—	1
Carp	25	267[2]	14	62[3]
Black bullhead	117	524	100	240
Burbot	24	—	—	2
Largemouth bass	51	129	179	104
Green sunfish	95	19	5	4
Bluegill	946	203	80	160
Orangespotted sunfish	917	—	—	11
White crappie	166	5	10	44
Black crappie	341	13	42	2,157
Yellow perch	1,558	33	111	1,130
Sauger	46	3	12	14
Freshwater drum	—	30	52	18
Minnows	241	968	1,074	1,126

[1] Common names as listed in, "A list of common and scientific names of the better known fishes of the United States and Canada", American Fisheries Society Special Publication No. 1, 1948.

[2] 265 taken from upstream extremity of reservoir.

[3] 57 taken from upstream extremity of reservoir.

overall supply of food for young fish was not wholly responsible for poor survival of carp. Although direct supporting data is not available, it is believed that the drawdown upset briefly some biological condition (such as food availability) at a critical stage in the life of the tiny fry, thus accomplishing the desired purpose of limiting reproduction.

Small numbers of unspent carp were caught throughout the summer in every year of study. However, there is no evidence of either spawning activity or successful reproduction subsequent to the major spawning periods. Several females were in various stages of egg absorbtion when caught late in the summer.

In addition to limiting carp reproduction, it is quite possible that planned drawdowns have limited reproduction of bigmouth buffalo *(Megastomatobus cyprinella)*, smallmouth buffalo *(Ictiobus bubalus)* and shortnose gar *(Lepisosteus platostomus)*. These species were observed spawning during the same periods and in the same general areas as carp and reproduced poorly in each of the three years. Shortnose gar eggs were observed every year in areas exposed by the drawdowns.

CONCLUSIONS

Results of the studies at Fort Randall Reservoir have been encouraging. The author and his co-workers are satisfied that correctly-timed water drawdowns in this reservoir have limited severely carp reproduction, and have caused an improvement in the ratio of desirable to undesirable fish.

In order to effect proper drawdowns, accurate data must be obtained concerning the depth, area, and periodicity of spawning, and the length of the spawning periods. These factors can be expected to vary to some extent in different lakes and in different areas of the country. Possible conflicts with production of other species present also must be studied and considered. It is possible, perhaps probable, that the technique is applicable to a limited number of water areas. However, its effectiveness at Fort Randall Reservoir should encourage further experimentation in other areas. In addition to control of carp reproduction, correctly manipulated water level has potentials of controlling other species or of improving conditions for desirable species. It is a management tool which deserves far more investigation than has been given it in the past.

ACKNOWLEDGEMENTS

Personnel of the Omaha office of the U. S. Army, Corps of Engineers through their interest, cooperation and detailed analyses of water supplies made possible the yearly drawdowns. John B. Owen made a detailed review of pertinent literature.

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CUI-UI IN PYRAMID LAKE, NEVADA

A fish peculiar to Pyramid Lake is the cui-ui[1]. Before the white man came there was no angling by Indians on the inflowing Truckee River or in Pyramid Lake itself. The Indians, whose only means of water transportation was crude rafts bound by tule waited for the cui-ui to run up the river to spawn. There they speared them as they came through the shallows. The cui-ui provided winter-time food. The back meat of the fish was stripped and smoked and stored. This practice is still followed by the Piutes on the Pyramid Lake Reservation. The aboriginal name of the lake in the Piute language meant "lake where the cui-ui live."

Extract from the Welcoming Address to the 87th Annual Meeting by LIEUTENANT-GOVERNOR REX BELL *of Nevada.*

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[1] The catostomid, *Chasmistes cujus* Cope. For a description of this fish see J. O. Snyder (1917); The fishes of the Lahontan System of Nevada and northeastern California, Bull. Bur. Fish. Vol. 35, pp. 33-86. Ed.

DISTURBANCE OF THE PREDATOR-PREY BALANCE AS A MANAGEMENT TECHNIQUE[1]

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Abstract

Disturbance of the predator-prey relationship may result in increased angler success and may sometimes provide an effective management tool. Exceptional harvest of walleyes *(Stizostedion vitreum)* in Clear Lake, Iowa, in 1951 is perhaps explained by reproductive failure of yellow perch *(Perca flavescens)* in 1950 and by elimination of young yellow bass *(Morone interrupta)* through more than normal predation. Stocking of 5 northern pike *(Esox lucius)* per acre in the fall of 1953 increased the weight of the predator population by about 10 percent In the first 6 weeks of the next fishing season, over 20 percent of the stocked northerns were caught by anglers.

Introduction

The mere presence of fish in a lake or stream does not always mean good fishing. Even large numbers of catchable size fish will not assure good angling. The fish must be biting if the average fisherman is to take a good string.

Seasonal changes in habits of the fish or in availability of food often may account for the fact that anglers cannot catch the fish. Extended seasons and year-round fishing are management methods whereby poor fishing from these causes can be improved. Further study on the changed habits may in some cases permit changes in angling methods so that the fisherman during "off" seasons might still make reasonable catches.

The principal game fishes are primarily predatory in their feeding. Various observations have suggested that the predator-prey balance may be an important factor in fishing success for these species and that manipulation of this balance may sometimes provide an effective management tool. The subject has been informally discussed for several years. Johnson (1949) presented part of the idea when he stated (p. 38): "Seining or trapping of forage fishes to reduce food supply or to improve angling for game species is now in vogue." He reported that in an 1,100 acre Minnesota lake the removal of 24 pounds of herring *(Leucichthys sp.)* per acre was followed by appreciably better angling for lake trout*(Salvelinus namaycush)* and that removal of 100 yellow perch per acre in a 124,000 acre lake gave better angling for walleyes.

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Bennett's recommendation (1954a) for lowering the water levels in reservoirs in late summer has as one of its goals a changing of the predator-prey relationship, not so much to increase catchability of the largemouth bass *(Micropterus salmoides)* as to increase reproduction of the bass the next summer. "These stresses, which in the case of draw downs might be related to available food supply, population density and/or predator-prey relationship, would have varying effects upon the several components of a fish population, not only among the species of fish present but also upon fish of various sizes belonging to a single species. The result might be that 'normal' intra- and inter-specific competition associated with stable water levels would be replaced by new types and intensities of competition favoring certain components of the fish population over others, and eventually changing the dominance of certain species in favor of others." (p. 260).

Spring draining of Ridge Lake with a resulting reduction of small bluegill, crayfish and other bass foods was followed by angler catches of higher than normal percentages of the available bass (Bennett, 1954b).

The present paper describes two situations in which improved fishing can probably be best explained as being the result of disturbance of the predator-prey balance.

Definition of Predator-Prey Balance

By predator-prey balance we do not mean to imply an exact or constant balance between the numbers or poundage of predators and prey but rather a "see-saw" type balance. When the prey increase there is a tendency for the predator to increase and thus bring about a balanced condition. If other factors prevent the proper increase of the predator population, the prey population may remain high with relation to the predator population, may actually increase because of the proportionally smaller predator pressure, or may decline through the action of other environmental factors. However, there will continue to be a tendency, perhaps unrealized, for the predator population to increase because of the availability of suitable prey.

The predator-prey balance is of importance in the present discussion primarily as an indication of feeding conditions for the predatory game fishes. When the ratio of predator to prey is high, the predator conceivably has greater difficulty in getting sufficient prey than when the ratio is lower.

Poor fishing may be the result of a low predator-prey ratio. The game fish may have a surplus of readily available forage fish. If the predator-prey ratio can be raised, by increasing the predators or by decreasing the prey, fishing success can be improved. Undoubtedly poor fishing is not always the result of a low predator-prey ratio, even in all cases when predator populations are known to be high enough so that they should provide fishing. The relationships are not as simple as stated here, and it may be that so many other factors are acting that control of the predator-prey ratio may often not be an effective management measure, but it is, I believe, a technique which should be considered.

Two Examples of Disturbance of Predator-Prey Balance

In the annual (since 1946) studies of fish populations of Clear Lake, Iowa, two situations seem to be best explained in the terms of disrupted predator-prey balance. Clear Lake is a 3,643 acre eutrophic lake with a maximum depth of 20 feet. It has a variety of warmwater fishes and each year provides over 150 hours of angling per acre and an annual harvest of over 60 pounds of fish per acre (Di Costanzo and Ridenhour, 1957).

The walleye is the most eagerly sought game fish, and 1951 will probably long be remembered as the walleye year at Clear Lake, because the catch was exceptionally good, particularly early in the season. Most of the walleyes were 4 to 7 years old and thus had been present in the lake the previous spring and summer when walleye fishing had not been particularly successful. The walleye catch in experimental gill nets was quite high in 1950 (18.0 per 125 foot net per 24 hours) but not much higher than in 1949 or 1952 (13.9 and 14.8 respectively) (Carlander, 1953). Following the high angler catch, the experimental gill net catch in 1951 was relatively low (5.1).

Why was the walleye fishing so much better in 1951 than in other years? Possibly because of the predator-prey relationship. Most years the young yellow perch provided an important source of food for walleyes. In 1950 extensive seining failed to reveal any young yellow perch in areas where they had previously been abundant.

It is believed that scarcity of aquatic vegetation in 1949 and 1950 may have been responsible for the failure of yellow perch reproduction. Without young yellow perch as forage the walleyes probably depended upon the young of other species, principally the yellow bass. The 1950 year class of yellow bass was fairly abundant but it disappeared during the winter of 1950-1. No yearling yellow bass were found in 1951. It is suspected that the more than normal predation by the walleyes may have eliminated the year class prior to the spring of 1951 and that the walleyes were hungrier than usual when the fishing season opened on May 15, 1951. The predator-prey balance had been somewhat disrupted through decrease of the prey (yellow perch and yellow bass) population and the catchability of the walleyes was thus increased.

Northern pike were a relatively small part of the population and of the angler's catch until 1953 and 1954. In the spring of 1951, a few adult pike were stocked in Ventura Marsh, a 630-acre marshy bay separated from Clear Lake by a road grade and a permanent fish trap. Many young northerns were raised in the marsh and released into Clear Lake through the fish trap in the fall, but no count was made of these young fish. In 1952, the same procedure was followed, except that more than 5,000 fingerlings were recorded as they moved into the lake (Moen and Lindquist, 1954). In the fall of 1953, about 17,000 young pike, 10 to 16 inches long, were transferred to Clear Lake from Ventura Marsh (Carlander and Ridenhour, 1955; Ridenhour, 1957).

When the fishing season opened in mid-May, 1954, the northern pike catch was unusually good. Tags from over 650 northern pike were turned in by anglers before July 1st. Over 20 percent of the fish tagged as they were stocked the previous fall were caught in the first six weeks of the fishing season. Many persons feared that the fishing was so heavy as to deplete the pike population.

The fishing success in this case was also probably due to disturbing the predator-prey balance. The fish population was probably fairly well balanced in 1953. There was no evidence of stunting nor of crowded populations of pan fishes such as occur where the predators are not sufficiently abundant to control the smaller fishes. We do not know how large a population of fish Clear Lake supports, but on the basis of comparisons with other rich lakes (Carlander, 1955) it probably has a standing crop of about 300 to 400 pounds of fish per acre. Studies on farm ponds and on food conversion indicate that there should be about 5 pounds of forage fish for each pound of predator. Thus Clear Lake might support about 50 to 70 pounds of predatory fish (such as walleyes, bass and pike) per acre. In the fall of 1953, about 5 pike per acre were stocked. By the spring of 1954 these fish averaged about 1.5 pounds. There were thus about 7 pounds of pike added—a rather abrupt increase of at least 10 percent in the predator population. Apparently even the fairly high harvest of the stocked northerns was not adequate to re-establish the balance, for later in the summer quite a number of thin northern pike were found dead along shore and some of the northern pike caught by anglers were in poor condition (Ridenhour, 1957).

It was thought that the disturbance of the predator-prey balance by the addition of the pike might increase the catch of walleyes, the other principal predator. No increase in the walleye catch was detected. Hazzard and Shetter (1939) reported that stocking one species of trout did not affect the catch of trout of another species but did increase the catch of stocked and native trout of the same species.

Discussion

Although many factors affect angling success and make the prediction of angling success very difficult, the predator-prey relationship appears to have considerable influence on the catch. Predator-prey balance may sometimes be disturbed by environmental changes such as drawdown, by destruction or failure of reproduction of fish food organisms, or by abrupt increases in the predator populations. These disturbances may come through natural changes or they may be engineered by man as a method of fishery management.

This type of management, of course, will not provide sustained good fishing. Successful angling results in lowering of the predator population and thus tends to bring the predator-prey relationship nearer a balance. The technique can thus be used primarily as a "shot-in-the-arm." It may provide for fishing success, when the fish are abundant, but not biting. It is primarily a method of increasing the rate of the harvest, not the production of fish.

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TOXICITY OF ORGANIC PHOSPHORUS INSECTICIDES TO FISH

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Abstract

Bioassays were made on ten organic phosphorus compounds, which are now in use or proposed for use as insecticides, to determine their comparative toxicity to fish. There was a wide range in toxicity of the different compounds with 96 hour TL_m (median tolerance limit) values ranging from 0.20 to 121 p.p.m. No relationship was apparent between toxicity and chemical structure. With one exception dilution waters with different characteristics (pH, alkalinity, and hardness) apparently had little or no effect on toxicity. Bluegills were somewhat more sensitive to several of these compounds than fathead minnows. The organic phosphorus compounds were less toxic to fish than many of the chlorinated hydrocarbon insecticides. No definite correlation could be established in the toxicity of organic phosphorus compounds between fish, insects and mammals.

Introduction

In the past few years many new insecticides have been developed. Most of these materials fall into two groups, the chlorinated hydrocarbon and the organic phosphorus compounds. It has been demonstrated that insects build up a resistance to some of these materials which has stimulated a search for even newer compounds. While the rapid development of new insecticides have assisted in the control of insect populations, many of these materials have been widely used without proper testing to determine their possible effects on fish and wildlife.

Large-scale application of some insecticides, such as in cotton dusting, orchard or forest spraying, and mosquito control may cause widespread destruction of aquatic life. Several such incidents, attributed to chlorinated hydrocarbon insecticides, have already occurred. (Surber and Bartsch, 1952; Springer, 1956; Rudd and Genelly, 1956).

The use of organic phosphorus insecticides has expanded rapidly until such names as EPN, TEPP, parathion, and malathion are well known, especially by orchardists who use them effectively for mite and aphid control (Rudd, 1954; Tech. Dev. Lab., 1956). Some of these and others are being developed and produced for other insecticidal purposes.

Organic phosphorus compounds are reported to be among the most highly toxic to mammals of any known chemicals with some having a higher mammalian toxicity than any of the chlorinated hydrocarbon insecticides

(Hayes, 1954; Lehman, 1949; Tech. Dev. Lab., 1956a). Some organic phosphorus compounds have been developed as possible chemical warfare agents (Eppstein, 1956). One of these compounds, Sarin (Isopropyl methylphosphonofluoridate), has been reported toxic to fish in concentrations as low as 0.002 p.p.m.

Several of the organic phosphorus insecticides, however, have been reported considerably less toxic to fish than Sarin. Parathion and TEPP have been reported toxic to certain warm water species in concentrations of 0.2 to 0.25 p.p.m. (Linduska and Surber, 1948), while malthion has been reported toxic to juvenile salmon at a concentration of 0.12 p.p.m. (Parkhurst and Johnson, 1955). These concentrations are considerably higher (toxicity lower) than some reported for chlorinated hydrocarbons such as DDT—0.04 to 0.14 p.p.m. (Surber, 1948). toxaphene—0.005 p.p.m. (Doudoroff et al, 1953), and dieldrin—0.006 p.p.m. (Tarzwell and Henderson, 1957).

However, the fact remains that some organic phosphorus compounds can be extremely toxic to fish. With continuing progress in the development and marketing of new insecticides, it is imperative that before such materials are widely used they be evaluated from the standpoint of toxicity to aquatic life as well as to humans and other animals. Information on the effects of organic phosphorus compounds on fish and wildlife is very limited. Fielding and Baldwin (1955) and Rudd and Genelly (1956) have summarized the available knowledge.

Bioassays were made on ten organic phosphorus compounds, now in use or proposed for use as insecticides, to determine their comparative toxicity to fish. Two dilution waters and two species of fish were used in the tests and a comparison was made with the toxicity of some of the chlorinated hydrocarbon insecticides in present use.

ORGANIC PHOSPHORUS COMPOUNDS

Among the compounds tested were organic phosphates, thiophosphates and phosphonates. Most of the compounds were obtained from manufacturers in the purest available form. Two samples of parathion were obtained from different manufacturers. As some of the compounds are not water soluble, it was necessary to use an organic solvent in order to prepare the bioassay test concentrations. Acetone was the solvent selected because it is relatively non-toxic (96 hour TL_m for fathead minnows—11,500 p.p.m. and readily miscible with water.

Following is a description of the compounds tested, including the chemical name, some pertinent properties, the original formulation, and the preparation used for bioassays. This information was obtained either from manufacturers literature (Pittsburg Agric. Chem. Co., 1951; Monsanto Chem. Co., 1950, 1953, 1953a; Chemagro Corp. 1955, 1955a) or from the following references (Martin, 1953; Metcalf, 1955; Tech. Dev. Lab., 1956, 1956a).

Para-oxon, technical

Chemical name—O, O-diethyl O-p-nitrophenyl phosphate. Properties—light yellow liquid; miscible with acetone and most organic solvents; solubility in water—20 p.p.m.; specific gravity—1.27. Formulation—technical grade, highest purity. Preparation for bioassays—0.1 percent acetone solution.

TEPP, technical

Chemical name—tetraethyl pyrophosphate. Properties—dark amber liquid; miscible with water, acetone, and most organic solvents; specific gravity-1.2. Formulation—40 percent TEPP, 60 percent other ethyl phosphates. Preparation for bioassays—one percent water solution.

Parathion, technical—Sample No. 1

Chemical name—O, O-diethyl O-p-nitrophenyl thiophosphate. Properties—dark brown liquid; garlic odor; miscible with acetone and most organic solvents; solubility in water—20 p.p.m. specific gravity—1.27. Formulation—99 percent parathion. Preparation for bioassays—one percent acetone solution.

Parathion, technical—Sample No. 2

Same as above, except formulation, which is 96.5 percent parathion and 3.5 percent inert ingredients.

Methyl parathion, xylene solution

Chemical name—O, O-dimethyl O-p-nitrophenyl thiophosphate. Properties—pure material is a white crystalline powder, very slightly soluble in water and soluble in most organic solvents. Formulation used was a brown liquid; specific gravity—1.26. Formulation—80 percent methyl parathion; 20 percent xylene. Preparation for bioassays—one percent acetone solution.

Chlorothion, technical

Chemical name—O, O-dimethyl-O-3-chloro-4 nitrophenyl thiophosphate. Properties—yellowish brown viscous liquid; solubility in water—40 p.p.m.; soluble in most organic solvents; specific gravity—1.43. Formulation—98 percent active ingredient. Preparation for bioassays—one percent acetone solution.

Systox, technical

Chemical name—O, O-diethyl O-2-ethyl mercaptoethyl thiophosphate. Properties—light brown liquid; solubility in water—20 p.p.m.; soluble in most organic solvents; specific gravity—1.12. Formulation—92 percent active ingredient. Preparation for bioassays—0.1 percent in water with triton emulsifier.

Malathion, 57 percent emulsifiable concentrate

Chemical name—O, O-dimethyl dithiophosphate of diethyl mercaptosuccinate. Properties—technical grade is a dark brown liquid; water soluble to the extent of 145 p.p.m. and miscible with most organic solvents. The formulation used was a light tan liquid; specific gravity—1.06. Formulation—57 percent malathion, 43 percent inert ingredients. Preparation for bioassays—one percent water emulsion.

OMPA, technical

Chemical name—octamethyl pyrophosphoramide. Properties—yellowish-brown liquid; soluble in water and acetone; specific gravity—1.11 Formulation—70 percent OMPA, 20 per cent related organic phosphates, 10 per cent inert ingredients. Preparation for bioassays—one percent water solution

Dipterex, technical

Chemical name—O, O-dimethyl-2,2-trichloro-1-hydroxyethyl phosphonate. Properties—pale yellowish crystalline powder; soluble in water to 13-15 percent and in most organic solvents. Formulation—99 percent Dipterex. Preparation—for bioassays—one percent water solution.

EPN-300

Chemical name—ethyl p-nitrophenyl thiobenzene phosphonate. Properties—technical grade is a dark amber liquid, only slightly soluble in water but soluble in most organic solvents. The formulation used was a grayish-white wettable powder. Formulation—25 per cent EPN, 75 percent inert ingredients. Praparation for bioassays—one percent water emulsion.

BIOASSAY METHODS

Bioassays were made, essentially, by the method recommended by the toxicity subcommittee of the Federation of Sewage and Industrial Wastes Associations (Doudoroff *et al.,* 1951). The laboratory setup and equipment was similar to that described by Henderson and Tarzwell (1957).

This method consists of preparing various concentrations of insecticide in a selected dilution water, adding the test fish, and observing their reactions for a definite time. For ease in plotting and interpreting results it is desirable to make up test solutions with p.p.m. of chemical in a logarithmic series as 10, 5.6, 3.2, 1.8, 1.0, etc.

As these chemicals were of unknown toxicity, exploratory small scale tests were made to determine the approximate toxic range. Test solutions were prepared over a wide range of concentrations (e.g. 100, 10, 1.0, 0.1 p.p.m.). Two fish were added to two liters of each concentration in 6½ inch diameter, 1-gallon widemouth glass bottles. Observations for a relatively short period (overnight) indicated test concentrations necessary for the full scale experiments.

In the full scale tests, ten fish were used in each test concentration. Five fish were added to 10-liter duplicate samples in five-gallon widemouth glass bottles, 10 inches in diameter. The intermediate concentrations tested were dependent upon information obtained from exploratory tests. For example, if fish were killed in concentrations of 10 p.p.m. and not in 1 p.p.m., intermediates were set up within this range (e.g 10, 5.6, 3.2, 1.8 and 1.0 p.p.m. of insecticide).

Two different dilution waters were used: (1) soft water prepared in the laboratory by mixing 95 parts of distilled, demineralized water and 5 parts of natural spring water; (2) hard water, a natural limestone water obtained directly from springs. These waters were allowed to come to the test temperature and aerated vigorously for about one hour to bring to equilibrium with atmospheric gases before using. At time of use for bioassays the average characteristics of these waters were as follows:

	Dissolved Oxygen p.p.m.	pH	Alka-linity p.p.m.	Hard-ness p.p.m.
(1) Soft Water	8.0	7.4	18	20
(2) Hard Water	8.0	8.2	360	400

The major test fish used were fathead minnows *(Pimephales promelas),* ranging in length from 2 to 2½ inches and in weight from 1 to 1½ grams. These fish were obtained in uniform lots from the State Fish Hatchery at Newton, Ohio and acclimated to laboratory conditions. This species is easily kept in the laboratory, is of intermediate tolerance to most chemicals and in this characteristic is comparable to bass, sunfish, perch, and other warm water species, and will tolerate fairly low oxygen conditions (1-2 p.p.m.). Bluegill sunfish *(Lepomis macrochirus)*, approximately 2 inches long and weighing 1½ grams, also obtained from the Hatchery, were used in some experiments.

Bioassays were made in a constant temperature room at 25°C, which would approximate summer water temperatures in many sections of the country.

The tests were designed so that no oxygenation or aeration was needed. Absorption of atmospheric oxygen by the exposed water surface was adequate for fish requirements during the test period.

Physical and chemical determinations (dissolved oxygen, pH, alkalinity, acidity, and hardness) were made on each test concentration initially, after fish mortality, or at the completion of the test. This was done primarily to detect low dissolved oxygen levels so they could be controlled if necessary and to determine other conditions which might have an effect on toxicity.

Fish reactions were observed over a 96-hour period. From the mortality in different concentrations, 24-, 48-, and 96-hour TL_m (median tolerance limit) values were obtained. The median tolerance limit is the concentration of chemical in dilution water that kills 50 percent of the test fish. These values were obtained by straight line graphical interpolation from points representing percent survival of fish and log concentrations of insecticide formulations which bracketed the 50 percent point (Doudoroff *et al.*, 1951).

Fresh preparations of the insecticide formulation, usually 1 percent in acetone or water, were made up and measured quantities added directly to the test aquaria (liquid formulations were measured on a volume/volume basis and solids on a weight/volume basis). Fish were then added and their reactions observed during the test period.

BIOASSAY RESULTS

A summary of bioassay results showing TL_m values of the different organic phosphorus formulations are presented in Table 1. The compounds are listed in the order given by Metcalf (1955). The first are phosphates, followed by thiophosphates, and finally phosphonates. Twenty-four, 48- and 96-hour TL_m values are shown for the two species of fish when using different dilution waters. The values are reported as parts per million by weight computed from the specific gravity of the formulations.

In most of the bioassays, only minor increases in fish mortality were observed between the 24- and 96-hour periods. This may be expected as most of these materials hydrolyze readily to less toxic materials. In solutions of TEPP, one of the most rapidly hydrolyzed (50 percent in 6.8 hours

(Metcalf, 1955) materials, no fish mortality occurred beyond the 24-hour period.

Two notable exceptions, however, were Dipterex and OMPA, which, while relatively less toxic than the other compounds, caused a considerable increase in fish mortality between the 24- and 96-hour periods. This may be partially explained by the fact that OMPA is slowly hydrolyzed (half-life-100 years in neutral water) and that Dipterex while readily hydrolyzed "is converted by mild alkali to the water insoluble and highly toxic O, O-dimethyl O-2-2-dichlorovinyl phosphate" (Metcalf, 1955).

TABLE 1.—*TL_m (median tolerance limit) values for organic phosphorus formulations*

Compound [1]	Dilution water	Kind of fish	TLm (median tolerance limit) p.p.m. formulation		
			24-hour	48-hour	96-hour
Para-oxon	Soft	Fatheads	0.41	0.37	0.33
Para-oxon	Hard	Fatheads	0.36	0.28	0.25
TEPP	Soft	Fatheads	1.7	1.7	1.7
TEPP	Hard	Fatheads	1.0	1.0	1.0
TEPP	Soft	Bluegills	0.84	0.84	0.84
TEPP	Hard	Bluegills	0.79	0.79	0.79
Parathion No. 1	Soft	Fatheads	1.6	1.6	1.4
Parathion No. 1	Hard	Fatheads	1.7	1.6	1.6
Parathion No. 1	Soft	Bluegills	0.83	0.71	0.71
Parathion No. 1	Hard	Bluegills	2.8	1.5	0.71
Parathion No. 2	Soft	Fatheads	4.8	2.9	2.8
Parathion No. 2	Hard	Fatheads	5.2	3.7	3.7
Methyl parathion	Soft	Fatheads	12.6	10.7	10.4
Methyl parathion	Hard	Fatheads	13.7	12.6	9.4
Chlorothion	Soft	Fatheads	5.0	3.4	3.3
Chlorothion	Hard	Fatheads	3.9	3.4	3.3
Systox	Soft	Fatheads	4.4	4.1	3.9
Systox	Hard	Fatheads	4.6	4.6	4.6
Malathion	Soft	Fatheads	25	23	22
Malathion	Hard	Fatheads	26	23	22
OMPA	Soft	Fatheads	> 1800	1600	135
OMPA	Hard	Fatheads	> 1800	> 1800	150
Dipterex	Soft	Fatheads	1800	1000	180
Dipterex	Hard	Fatheads	560	180	51
EPN-300	Soft	Fatheads	2.2	1.5	0.80
EPN-300	Hard	Fatheads	1.1	1.05	1.0

[1] Formulation as described in text.

It is not known what effect exposure for a longer period or what effect a continuously renewed solution may have. It appeared, however, that 96 hours was not an adequate period to obtain valid toxicity data for such compounds as OMPA and Dipterex. Some preliminary experiments with parathion in a continuously renewed solution indicated no greater toxicity than obtained in the previously described static bioassays.

The phosphates, para-oxon and TEPP, were among the most toxic of the compounds tested. The thiophosphates were somewhat less toxic, with parathion the most and malathion the least toxic of this group. Some difference in the toxicity of the samples of parathion from different manufacturers was found, with one sample approximately twice as toxic as the other. OMPA was considerably less toxic than compounds in either of the above groups. The two phosphonates were greatly different, EPN being among the most toxic and Dipterex among the least toxic of any of the compounds.

During the course of the bioassays, physical and chemical characteristics of the test solutions such as dissolved oxygen, pH, alkalinity, and hardness were not greatly altered from those of the dilution waters. Dissolved oxygen values remained between 4 and 8 p.p.m. in all test concentrations of all compounds during the 96-hour period. Apparently, there was little or no oxygen demand from these materials in the concentrations tested. In the higher concentrations of OMPA and Dipterex, the pH levels were reduced about one unit but in all cases remained between 6.5 and 8.5. Levels of both oxygen and pH were well within limits expected to support the test fish.

The physiological reaction of the fish was somewhat similar for most of these compounds; however, the response time was considerably different. Usually, the first noticeable change was a darkening of the skin. This was followed by a period of high excitability with body tremors and then complete loss of equilibrium. Sometimes death did not occur for many hours after equilibrium was lost. This response was similar to that observed when working with some of the chlorinated hydrocarbon insecticides.

A response characteristic of the organic phosphorus compounds, which has not been observed with other chemicals, however, was the extreme forward position of the pectoral and pelvic fins when the fish were affected.

EFFECT OF DIFFERENT DILUTION WATERS

Because organic phosphorus compounds, when used as insecticides, may enter different types of water, and since the toxicity of many chemicals is dependent upon receiving water characteristics such as pH, alkalinity, and hardness, tests were made to determine if major differences occurred in the toxicity of these compounds when using different dilution waters. The soft and hard waters (as previously defined) used in the bioassays encompass the pH, alkalinity, and hardness range of most natural waters.

A direct comparison of the toxicity of the compounds tested in soft and hard water, based on p.p.m. of active ingredient, is shown in Table 2. While it might be expected that most of these compounds would be somewhat less toxic in hard water, due to the increase in hydrolysis rates in the more alkaline media, the results do not bear this out. Some of the compounds were slightly less toxic in hard and some in soft waters with no definite pattern established. Most of the results were within the range of experimental error that may be expected in bioassays when using ten fish. The only compound in which there was a major difference was Dipterex for which a much greater toxicity was shown in hard water. This may have been due to the more rapid breakdown to toxic products in the more alkaline water as already discussed.

TABLE 2.—*Comparison of the toxicity of organic phosphorus compounds to fathead minnows in soft and hard waters.*

Compound	Percent active ingredient	96-hour TL_m p.p.m. active ingredient	
		Soft water	Hard water
Para-oxon	100	0.33	0.25
TEPP	100	1.7	1.0
Parathion No. 1	99	1.4	1.6
Parathion No. 2	96.5	2.7	3.6
Methyl parathion	80	8.3	7.5
Chlorothion	98	3.2	3.2
Systox	92	3.6	4.2
Malathion	57	12.5	12.5
OMPA	90	121	135
Dipterex	99	180	51
EPN	25	0.20	0.25

From these experiments, it is indicated that toxicity of most of these oganic phosphorus compounds would not differ greatly in different receiving waters.

TOXICITY TO DIFFERENT SPECIES OF FISH

A comparison of the toxicity of TEPP and parathion to bluegills and fathead minows (Table 1) indicates that bluegills are somewhat more sensitive. While no information is available on the other organic phosphorus insecticides, Surber (1948) reports approximately the same relationship between minnows and bluegills (bluegills more sensitive by a factor of two) for toxaphene and DDT. Tarzwell and Henderson (1957) report a similar relationship for dieldrin.

With respect to cold water species, Surber (1948) reports approximately the same sensitivity of rainbow trout *(Salmo gairdneri)* and bluegills to DDT; however, trout were slightly more sensitive to toxaphene and the gamma isomer of BHC than were bluegills. Mayhew (1955), in studies of the toxicity of seven chlorinated hydrocarbon insecticides to rainbow trout, reports toxic values within the same range as those reported by other workers for several species of warm water fish. Apparently for most chlorinated hydrocarbon insecticides, the variability in toxicity to many common species of fish is not great, possibly by no more than a factor of two or three. The results reported by most fisheries workers are in fairly close agreement.

Organic phosphorus compounds, however, may differ considerably in their effects on different species of fish. Linduska and Surber (1948) report the toxicity of parathion as approximately the same for bluegills and rainbow trout (0.3 p.p.m.) a value not greatly different from that reported here for bluegills. Epstein (1956) reports a relatively minor difference in the sensitivity of goldfish, sunfish, and minnows to Sarin (0.002 p.p.m.), again a value similar to that reported here. However, Parkhurst and Johnson (1955) report for malathion a 96-hour TL_m value of 0.12 p.p.m. when using fingerling chinook salmon *(Oncorhynchus tshawytscha)*, which is at wide variance with the 96-hour TL_m value of 12.5 p.p.m. reported here for fatheads. The relative tolerance of various species of fish to these chemical needs further investigation.

Comparison with Chlorinated Hydrocarbon Insecticides

A comparison of the toxicity to fish of organic phosphorus compounds with that of some common chlorinated hydrocarbon insecticides and with

TABLE 3.—*Comparison of the toxicity to fish of organic phosphorus with chlorinated hydrocarbon compounds and with rotenone and cyanide.*

Organic phosphorus		Chlorinated hydrocarbon	
Compound	96 hour TL_m p.p.m.[1]	Compound	Toxic to fish p.p.m.
EPN	0.20	Toxaphene	0.004[2]
Para-oxon	0.25	Dieldrin	0.016[2]
Parathion	0.70	Aldrin	0.018[3]
TEPP	0.79	DDT	0.04-0.14[4]
Chlorothion	3.2	Lindane	0.10[5]
Systox	3.6	Methoxychlor	0.20[6]
Methyl parathion	7.5	Chlordane	0.20[6]
Malathion	12.5	BHC, tech.	0.45[7]
Dipterex	51		
OMPA	121		
Sarin	0.0032	Rotenone	0.011[2]
		Cyanide	0.24[2]

[1] Maximum toxicity (minimum TL_m) values during this study.

[2] 96 hour TL_m—Fathead minnows—Soft water.

[3] 10 day TL_m—Fathead minnows (Doudoroff et al 1953)

[4] 100 percent mortality—Bluegills, bass and minnows (Surber, 1948).

[5] 50 percent mortality—Bluegills (Lawrence, 1950).

[6] 100 percent mortality—Bluegills and bass (Lawrence, 1950).

[7] No effect on Bluegills (Surber, 1948).

rotenone and cyanide is shown in Table 3. All of the values are not directly comparable as some represent 50 percent mortality values (TL_m) and some 100 percent mortality. The 100 percent mortality values, however, would not be expected to differ from the others by more than a factor of two. All values are for warm water fish of comparable sensitivity.

As can be readily seen from this table, many of the chlorinated hydrocarbons are more toxic to fish than the most toxic of the organic phosphorus compounds (except Sarin which is not proposed for insecticidal use). Reasons for this are not known but may be due to an entirely different physiological action exerted by the two types of compounds or to the fact that the organic phosphorus materials hydrolyze more readily or that the degree of absorption by fish may be different.

It is believed (Kodama *et al.,* 1955) that the toxicity of organic phosphorus compounds is due to one or more of the following effects: (1) cholinesterase inhibition; (2) selective degeneration in the central and peripheral nervous systems; (3) stimulation and depression of the central nervous system; and (4) irritation of surface tissues. Among the organophosphorus compounds studied (Kodama *et al.,* 1955), a high degree of acute toxicity was found only among those phosphates and phosphonates which profoundly inhibit cholinesterases.

The chlorinated hydrocarbon insecticides act on the central nervous system but the exact mechanism has not been elucidated (Tech. Dev. Lab. 1956a).

From the toxicity data given, it would appear that most of the organic phosphorus insecticides would be less hazardous to aquatic life than many of the chlorinated hydrocarbons. This conclusion, however, would well bear future checking in field scale experiments.

COMPARATIVE TOXICITY TO FISH, INSECTS AND MAMMALS

Comparative toxicity values for the organic phosphorus compounds to fathead minnows, houseflies, and white rats are shown in Table 4. As the route of administration is different the numerical values for the different animals would not be directly comparable. However, the values give an indication of insecticidal efficiency of the compound in relation to the possible effect on fish life and the potential danger to humans or other animals from drinking water and foodstuffs.

Comparable oral LD_{50} values for rats (in milligrams per kilograms of body weight) of some of the chlorinated hydrocarbon insecticides (Tech. Dev. Lab., 1956a) are as follows:

Dieldrin	46	Lindane	200
Toxaphene	90	Chlordane	335
DDT	146	Methoxychlor	6000

For comparison rotenone has a value of 132. If these values are compared with fish toxicity values in Table 3, a somewhat closer correlation is apparent between fish and mammalian toxicity than is shown by the organophosphorus compounds.

TABLE 4.—*Comparative toxicity of organic phosphorus insecticides to fish, insects, and mammals*

Compound	Fathead minnows 96 hr TL_m (*1*) p.p.m.	House fly (*M. domestica*) Topical LD_{50} (*2*) micrograms/gram	White rats Oral LD_{50} milligrams/ kilogram
EPN	0.20	1.9	12-40[2]
Para-oxon	0.33	0.5	3-3.5[2]
Parathion	1.4	0.9	13.0[3]
TEPP	1.7	—	2.0[3]
Chlorothion	3.2	16.5	880[2]
Systox	3.6	—	6.2[3]
Methyl parathion	8.3	1.0	14-42[2]
Malathion	12.5	28	1375[3]
OMPA	121	—	10[2]
Dipterex	180	—	630[3]

[1] Standardized conditions—soft water.
[2] Values from Metcalf (1955)
[3] Values for male white rats under standarized conditions. From Technical Development Laboratories (1956a).

It is apparent from the table that there is no definite correlation between the three columns. While there is some correlation between the insect and rat columns, neither has any correlation with the fish column. Perhaps this suggests that experimentation with other laboratory animals cannot indicate possible effects of these compounds on fish.

It will also be observed that while many of the organic phosphorus insecticides are apparently less toxic to fish they are much more toxic to mammals than the chlorinated hydrocarbons.

The TL_m values given in this paper should in no manner be construed as safe concentrations for aquatic life. These values are concentrations of insecticides which will kill 50 percent of a moderately sensitive warm water fish upon relatively short time exposure. These values may serve, however, as a comparison to obtain the relative toxicity of members of a group of compounds having similar physiological effects. On the basis of the limited knowledge available, it may be expected that a safe concentration for the test fish would be approximately ½ of this value while a safe concentration for all aquatic life may be as little as 1/10 depending on the kind of fish and other organisms as well as physical and chemical conditions of the receiving water. Also, different formulations (suspensions, emulsions, solutions) of the same compound may have different degrees of toxicity (Surber, 1948; Tarzwell, 1950; Tarzwell and Henderson, 1957).

Further experimentation is needed to determine the toxicity of these and other compounds to various species of fish and other aquatic organisms at different stages in their life histories as well as to determine conditions under which the toxicity may differ. Information would be much more useful if obtained on a comparable basis.

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STATISTICS OF A WALLEYE SPORT FISHERY IN A MINNESOTA LAKE[1]

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ABSTRACT

Data on walleye *(Stizostedion v. vitreum)* population dynamics and angling statistics from a northwestern Minnesota Lake are presented. Many Point Lake has an area of 1,716 acres, and in years studied (1955-1957) had an average annual fishing pressure of 17 man-hours per acre. The average annual harvest of fish of all species was 7.5 pounds per acre of which about 60 percent was walleyes and pike, *(Esox lucius)*. To study relationships between the walleye population and catch, 3,249 adult walleye were marked with distinguishing fin clips during the three years, and these fish tallied in anglers' catches. By application of appropriate statistics it is concluded that, on the average, 26.8 percent of the adult walleye population was taken by anglers each year. Loss of adult fish from natural causes was found to be about 4 percent per year.

Walleye of age-group III averaged 8.4 ounces in weight, but during the next four years the fish increased in weight at an average rate of 7.6 ounces per year, the accelerated average growth of the older fish largely reflecting rapid weight increase of female fish. The angling harvest was 3,402 walleyes weighing 4,826 pounds in 1955, 4,973 fish weighing 6,292 pounds in 1956, and 3,730 walleyes weighing 4,215 pounds in 1957. During the years studied, recruitment exceeded loss from total mortality and the population of walleyes, three and more years old, increased from an estimated 11,546 in 1955, to 14,675 in 1956, and 18,220 in 1957.

Application of population and catch data to a mathematical model indicates that with present growth and natural mortality rates, a higher sustained yield in pounds could be had at lower fishing intensity. This would allow a yield of fewer fish but of larger average size. It is pointed out, however, that an attempt to create a larger sustained yield in pounds at a lower fishing intensity might not be realized because of compensatory changes in growth and natural mortality.

INTRODUCTION

Knowledge of fish population dynamics is necessary for proper evaluation of management techniques and for wise regulation of sport fishing harvest. Population and mortality estimates based on the recapture of marked fish have usually been confined to ponds and small lakes because of practical limitations of a program of marking fish, determining harvest and sampling fish populations in larger bodies of water. Many Point Lake, a large natural walleye lake in northwestern Minnesota, is particularly suitable for a study of population and yield because large numbers of walleyes can be easily trapped and marked during their spawning migration and because almost complete census coverage can be attained by one census clerk during the summer angling season.

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[1] Investigational Report No. 188, Fisheries Research Unit, Bureau Research and Planning.

The three-year investigation of the Many Point Lake walleye fishery reported here was designed to give information on the inter-relationships of natural and fishing mortality, growth, recruitment and population size.

MANY POINT LAKE AND ITS RECENT FISH MANAGEMENT HISTORY

Many Point Lake, located in Becker County of northwestern Minnesota, has a basin that is irregular in outline and a surface area of 1,716 acres. Maximum depth is 90 feet and approximately 40 percent of the lake is deeper than 30 feet. During the periods of greatest fish growth, July through September, the lake is thermally stratified and has insufficient oxygen to support fish life at depths greater than 30 feet. This stratification is probably a major limitation to the carrying capacity of the lake. The water is moderately fertile having a total alkalinity of 159 p.p.m. but is somewhat low in phosphorus[2] compared to many other Minnesota waters (Moyle, 1956). Temperature of the surface water in July and August ranges from 68° to 76° F. No heavy algal blooms occurred during the investigation period and secchi disc readings were mostly between 8 and 12 feet. Bottom soils are varied with rubble, gravel, sand, muck, clay, peat and marl, found separately and in combination. Emergent vegetation is largely bulrush (Scirpus acutus) which extends to a depth of five feet along much of the shoreline. Submerged vegetation is moderately abundant to a depth of about 15 feet.

The Ottertail River, a tributary of the Red River of the North, flows through the lake. A four-bay stop-log dam, each bay five feet wide, is located at the inlet and a similar five-bay structure is present at the outlet.

Fishes known to be present, exclusive of the minnows and darters, are: bowfin *(Amia calva)*, tullibee *(Coregonus [Leucichthys] artedi tullibee)*, whitefish *(Coregonus clupeaformis)*, white sucker *(Catostomus commersoni)*, northern redhorse *(Moxostoma aureolum)*, brown bullhead *(Amieurus nebulosus)*, yellow bullhead *(Amieurus natalis)*, pike *(Esox lucius)*, yellow perch *(Perca flavescens)*, yellow walleye *(Stizostedion vitreum)*, pumpkinseed *(Lepomis gibbosus)*, rock bass *(Ambloplites rupestris)*, bluegill *(Lepomis macrochirus)*, black crappie *(Pomoxis nigro maculatus)*, largemouth black bass *(Micropterus salmoides)*, smallmouth black bass *(Micropterus dolomieu)*.

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[2] Mean of seven surface water analyses made at intervals in the summer of 1956: sulphate ion 3.6 p.p.m., ammonia 0.048 p.p.m., organic nitrogen 0.50 p.p.m., total nitrogen 0.60 p.p.m., phosphorus 0.012 p.p.m., total alkalinity 159 p.p.m.

The fish population was sampled with experimental gill and trapnets during the summers of 1954 through 1957. The results of netting surveys indicate large populations of perch, common suckers, rock bass and walleyes Pike, bowfin, tullibee, bullheads, pumpkinseeds and bluegills were also common in the nets. Black crappies, largemouth black bass and smallmouth black bass were caught occasionally. Only one specimen each of whitefish and northern redhorse were taken.

Many Point Lake has been stocked with walleye fry or fingerling in seven years since 1945. The stocking record is as follows:

Year Stocked	*Number*	*Size*
1945	3,500	Fingerling
1948	600,000	Fry
1949	60,450	Fingerling
1950	800,000	Fry
1952	3,030	Fingerling
1956	99,780	Fingerling
1957	117,600	Fingerling

Although it is not possible to determine the contribution of stocking to the fishery, it is known that large walleye year classes of 1953 and 1954 are from natural reproduction. Heavy fingerling stocking in 1956 and 1957 have not yet had time to be recruited to the fishery.

INVESTIGATIONAL METHODS

CREEL CENSUS AT MANY POINT LAKE

Census of the anglers' catch was started in 1955 and was continued through the 1956 and 1957 angling seasons. It is believed that at least 98 percent of the total fishing trips were recorded during the three-year period. This high census coverage was possible because most of the fishing trips originate from a group of three resorts and eight private cottages located near the inlet. One census clerk was able to contact all anglers at this location from the opening of the walleye angling season in May until fishing declined to one or two trips per day in early October. During the period of light fishing pressure in October, the census was voluntarily continued by the resort operators. The lake is seldom fished through the ice in winter and the harvest during the period of open water is considered to be the total annual yield. Catch rate for walleyes is shown in Figure 1 and angling harvest in Table 6.

About 5 percent of the total recorded fishing trips is of trips that were not directly contacted by the census clerk, but which were voluntarily recorded by personnel at the Many Point Boy Scout Camp and by the occupants of the four private cottages located outside of the main census area.

Current Minnesota sport fishery regulations were in force at Many Point Lake and allowed the angler a daily limit of six walleyes of any size.

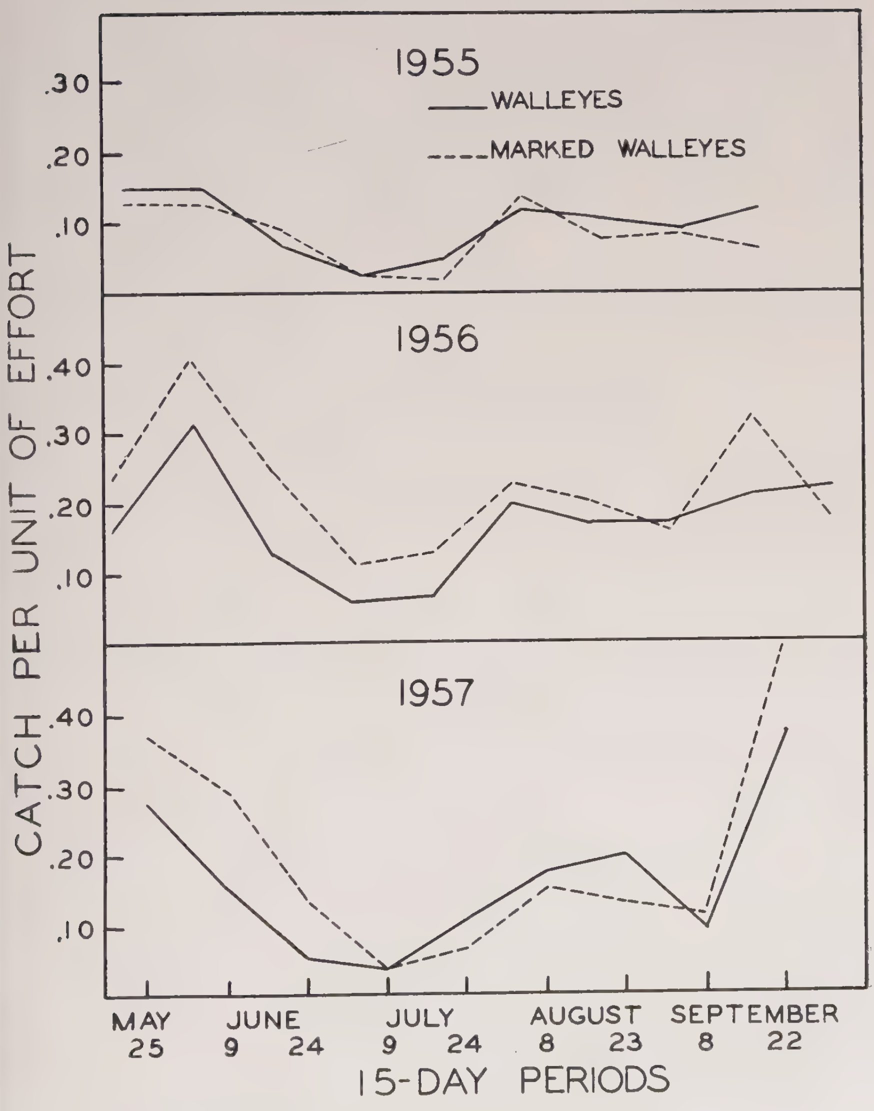

FIGURE 1.—Catch as walleyes per man-hour and marked walleyes per man-hour X10 during 15-day periods in the 1955, 1956 and 1957 summer angling seasons.

INITIAL FIN-CLIPPING AND RE-MARKING OF FIN-CLIPPED WALLEYES IN SUBSEQUENT SPAWNING RUNS.

Walleyes were captured for marking during spawning migrations in a pound net of 1-inch bar-measure webbing set in the mouth of the inlet about 250 feet below the dam (Fig. 2). With the trap in place it was possible to capture nearly all walleyes attempting to move up stream, except for fish which were able to escape through muskrat and beaver holes in the webbing before such holes could be discovered and repaired. During the 1955 spawning migration, a considerable number of fish escaped through holes in the webbing, but with increased vigilance in 1956 and 1957 these holes were repaired immediately and it was possible to capture nearly the entire runs of migrating walleyes.

To insure that marked walleyes would be of a size completely acceptable to the angler, a total-length of 14 inches was established as a minimum size for marking. This minimum size is believed to have excluded all walleyes which were less than 4-annulus fish in the current season. The sex and length of each fish were recorded and a sample of scales was taken for age determinations. All marked fish were released at the marking station from which they could move either down stream to the lake or up stream to the dam.

Using an ordinary heavy-duty scissors, the left pectoral fin was removed from 1,039 adult walleyes during a 7-day spawning period in April 1955. In early May of the following year (1956), 1,369 walleyes were marked by removal of the left pelvic fin. In addition, 346 walleyes marked in 1955 were recaptured in the 1956 spawning run. Any regeneration of the left pectoral fin was trimmed but these fish were not also marked by the 1956 mark. Trimmed fins were easily distinguishable from 1955 marks which had not been trimmed, eliminating the possibility of counting recaptured fish more than once.

During the 1957 spawning migration, the right pectoral fin was removed from 1,581 adult walleyes. Of this number, 841 had not been marked in previous years, 288 had been marked in 1955, and 452 were fish bearing the 1956 mark. From double-marking additional information could be obtained for comparison of known ratios of marked fish with observed ratios in the anglers' catch. Female walleyes in the 1957 spawning run, were identified by clipping the anal fin in an attempt to detect any difference in the anglers' catch of males and females.

Assumptions of Population and Mortality Estimates as Applied to Many Point Lake

In making the following estimates of walleye populations and mortality rates, certain basic assumptions which involve primarily the effect and durability of the mark and the randomness and efficiency of the sampling procedure must be made. A consideration of these factors as outlined by Ricker (1948) follows:

(1) *That the marked fish suffer the same natural mortality as the unmarked fish.*

There is no indication that marking and handling caused increased mortality. Although no controlled study was attempted, it was possible each year to observe a large number of marked fish that congregated in a 250-foot section of the river between the trap and the dam. These fish were observed each day during the marking periods but no dead clipped fish were found.

Only one dead clipped walleye was reported during the three-year period. This was a fish marked in 1956, which was picked up in July of the same year. The cause of death is unknown.

Although no differential mortality is believed to have occurred, it was definitely established that marking and handling caused an increase in the occurrence of *lymphocystis.* The incidence of *lymphocystis* among marked fish in the spawning runs was more than three times that of the unmarked fish. Characteristic growths were often present in the area where scale samples had been taken and on the stub of the clipped fin. Fortunately, this disease nearly disappears during the summer and few fish showing symptoms were taken by anglers.

(2) *That marked fish do not lose their mark through fin regeneration.*

Error from failure to recognize regenerated fins is not considered to be great. Fin regeneration of 54 pectoral fin-clips recovered in the 1956 spawning run was measured and lengths of the regenerated fin and opposite normal fin were recorded. The average length of the regenerated fin was 33.4 percent of the opposite normal fin one year after marking.

Although clipped fins of individual fish showed as much as 50 percent regeneration in one year, a trained observer had little difficulty in distinguishing marks. New fin growth had prominent deformities in form and structure and in most cases a transverse line was evident at the base of the new growth. No natural fin deformities which could be mistaken for fin-clips were observed during the marking periods.

(3) *That the marked fish are as vulnerable to the fishing being carried on as are the unmarked ones.*

Available information indicates that marking did not cause a change in the vulnerability of the marked fish. An attempt to detect a change in vulnerability was made by comparing the fluctuations in the catch per unit of effort of marked and unmarked fish by 15-day intervals throughout the summer seasons (Fig. 1). This comparison indicated that the factors which influenced fishing success had a similar effect on both marked and unmarked fish.

The effects of marking on fish behavior may also be examined by comparing the percentage return of fish bearing different clipped fins and combinations of clipped fins returned by anglers in 1957 (Table 1). If fin removal had caused any great change in vulnerability, it seems quite possible that such changes may have operated at various intensity with different combinations of fins removed. The small variation in percentage return of different combinations of marks strengthens the assumption that marking did not cause a change in vulnerability.

TABLE 1.—*Angling return of marked walleyes with various combinations of marked fins during the 1957 season.*

Type of mark	Year of mark	Number present at beginning of the 1957 season	Number returned	Percent returned
Left pectoral	1955	144[1]	30	20.9[1]
Left pectoral and Right pectoral	1955 1957	288	67	23.3
Left pelvic	1956	383[1]	80	20.9[1]
Left pelvic and Right pectoral	1956 1957	452	97	21.3
Right pectoral	1957	841	166	19.7
Totals Average		2108	440	 20.9

[1] Estimates based on a 20.9 percent return of fish bearing the 1957 mark.

(4) *That the marked fish become randomly mixed with the unmarked; or that the distribution of fishing effort is proportional to the number of fish present in different parts of the body of water.*

The fulfillment of this assumption is strongly supported by an inspection of the location of return by anglers of marked walleyes (Fig. 2). Anglers were questioned as to the location of capture of marked fish and in most cases could identify the various points, bays or bars near which they were fishing.

In view of the widely scattered return of marked fish there is no reason to suspect that the procedure was not random in the return of marked and unmarked fish.

(5) *That all marks are recognized and reported on recovery.*

With the inspection of nearly 95 percent of the total recorded catch by a trained census clerk, the possible error from failure to recognize and report marked fish, is considered to be quite small. Walleyes which were reported caught outside the main census area (about 5 percent of the total catch)

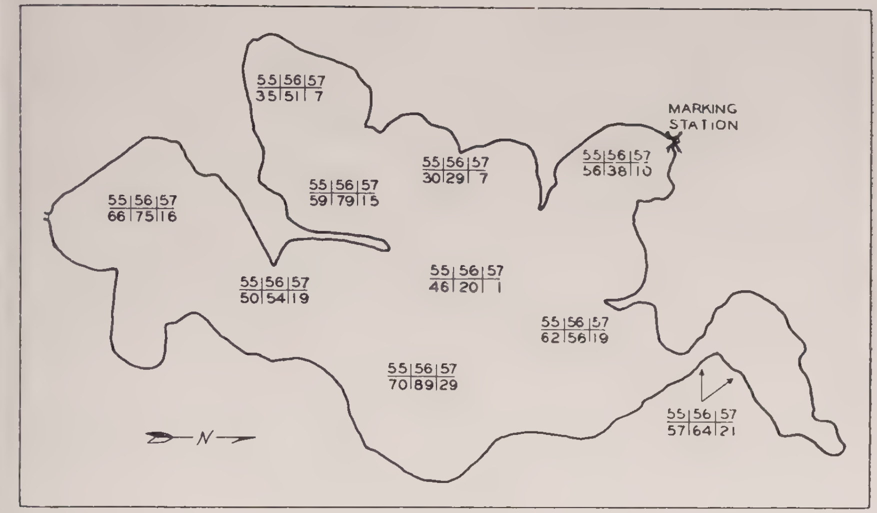

FIGURE 2.—Approximate location of recapture of 531 walleyes marked in 1955, 555 walleyes marked in 1956 and 144 walleyes marked in 1957. [*The figures "55, 56 and 57" at each location denote the years of marking, and not the years of recapture.*]

and which were not observed by the census clerk, were recorded separately and the estimated number of marks in this group was calculated by applying the observed ratio of marked to unmarked fish.

(6) *That there is only a negligible amount of recruitment to the catchable population during the time the recoveries are being made.*

Recruitment to the catch of young walleyes through growth during the periods of investigation will cause the estimated size of the original population of catchable-size walleyes to be too large. In this study, however, population estimates were restricted to walleyes three years old and older which nearly eliminated the effects of recruitment since it is believed that anglers retain all four-year-old walleyes and it is estimated that three-annulus fish are about 90 percent acceptable to the angler. Anglers' acceptance of small walleyes will vary somewhat from year to year depending on the availability of larger size fish. However, it is believed that a 90 percent acceptability factor applied to the catch of three-annulus fish each year will be adequate in describing the anglers retention of this group.

In addition to the assumptions which have been discussed, it is also assumed that walleye movement into or out of the lake is restricted. The lake is considered closed to immigration, but there is a possibility that fish may move out by passing over the dam at the outlet. Emigration would not influence population estimates, but would cause the rate of exploitation to be too low and estimates of natural mortality to be too high. However, as will be shown in a later section, loss of marked fish from natural causes is estimated at less than 5 percent annually, of which an indistinguishable part may be due to emigration.

In a strict sense, the estimates for the Many Point Lake fishery apply only to the population of mature walleyes since only spawning-run walleyes were marked. It is assumed here that within the range of completely-acceptable-size walleyes, the harvest of each age or size group is proportionate to their abundance. If this assumption is true, the rates of exploitation indicated by the return of marked fish apply also to the "catchable size' population. Histograms of length-frequency distributions of marked fish returned by anglers (Fig. 3) are similar in shape to those for the marked fish from which the catch came, indicating that marked fish of different sizes were harvested in proportion to their abundance.

About equal vulnerability to the angler of marked males and females was indicated by a 22.6 percent return by anglers of 327 females marked in 1957 as compared to a 20.3 percent return of 1,251 marked males.

EXPECTATION OF DEATH FROM NATURAL CAUSES

Natural mortality of marked fish is estimated for the 12-month periods between the opening dates of walleye angling seasons. The known number of marked fish removed during the period, plus the estimated number of marked fish which survived, are subtracted from the number present at the beginning of the period; the difference is considered to be loss from natural causes. Expectation of death from natural causes is described by the equation:

$$v = \frac{a - (b + c + d)}{a}.$$

Where:

v is the expectation of death from natural causes,
a is the number of marked fish at the beginning of the year,
b is the number of marked fish removed by anglers during the year,
c is the number of marked fish removed in gill nets during the year, and
d is the estimated number of marked walleyes that survived to the following fishing season.

The number of marked walleyes that survived from the spring of 1955 to the spring of 1956 is estimated by applying the Peterson ratio to the 1956 angling return of 231 walleyes bearing the 1955 mark and to 448 of 1,369 walleyes marked in 1956 (Table 2). Survival is estimated as

$$\frac{(1369)\ (231)}{448} = 706 \text{ marked walleyes.}$$

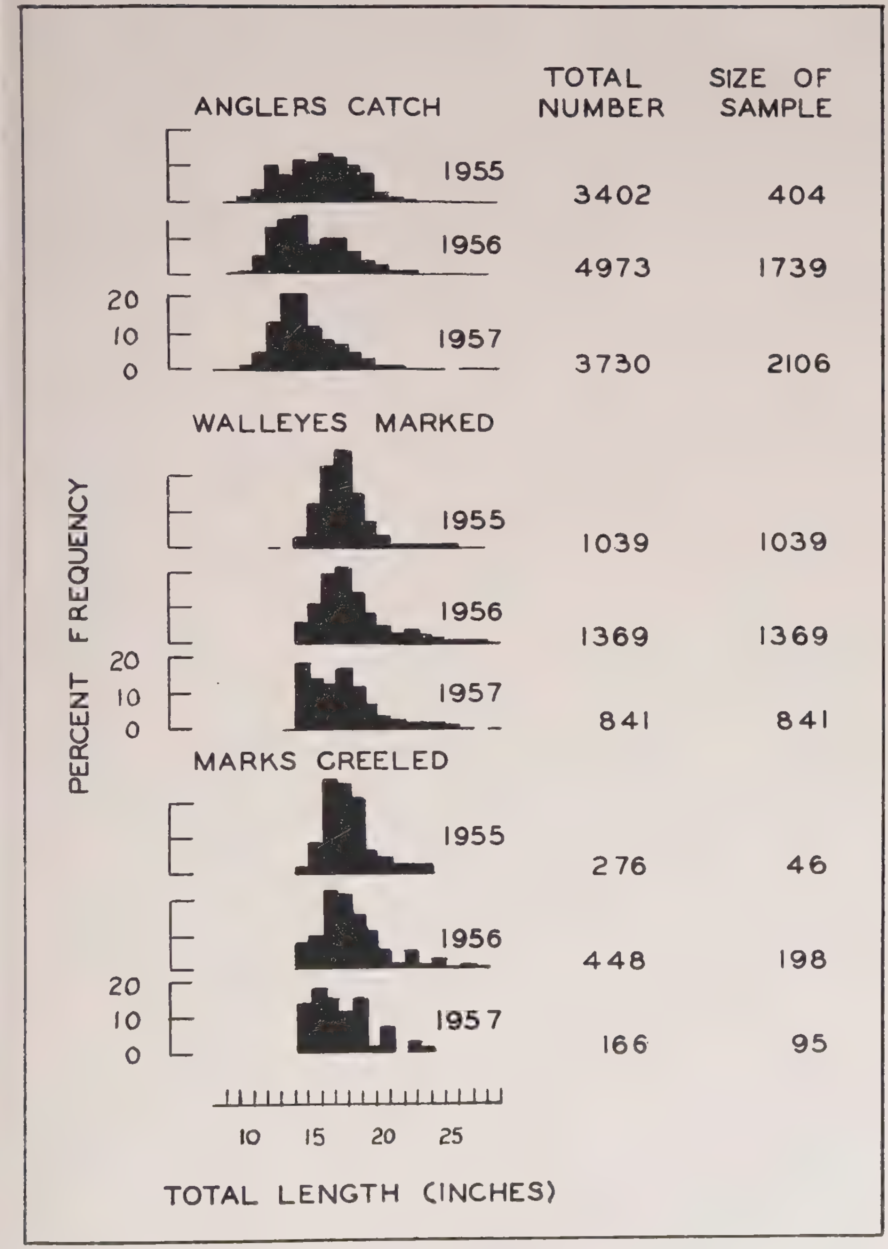

FIGURE 3.—Percentage length-frequency distributions of walleyes caught by anglers, walleyes marked in spawning runs, and marked walleyes returned by anglers during the summer following marking.

TABLE 2.—*Angling return of marked walleyes by year marked and year returned.*

Year returned by anglers	Year marked				Total returned
	1955 (left pectoral) (1039 marked)	1956 (left pelvic) (1369 marked)	1957 (right pectoral)		
			(841 marked)	(1581 marked)[1]	
1955	276	—	—	—	276
1956	231	448	—	—	679
1957	97	177	166	330	440
Total returned.	604	625	166	—	1,395

[1] Includes 841 walleyes marked only in 1957, 288 walleyes remarked but marked originally in 1955 and 452 alleyes previously marked in 1956.

Of the 1,039 marked walleyes present at the beginning of the 1955 angling season, 276 were returned by anglers and 7 were removed by gillnet sampling of the population during the 1955 season. Using these figures in the equation already given, expectation of death from natural causes is calculated as .048.

By the same method expectation of death from natural causes from the spring of 1956 to the spring of 1957 was calculated as .033 for the combined groups of 1,369 walleyes bearing the 1956 mark and 706 walleyes marked in 1955 which were estimated to have survived to the spring of 1956. This estimate is calculated from the anglers catch in 1957 of 97 of the fish marked in 1955, 177 of the fish marked in 1956, and 330 of 1,581 walleyes bearing the 1957 mark. Netting during the summer of 1956 removed 8 of the fish marked in 1955 and 7 of the fish marked in 1956.

Average expectation of death from natural causes for the two years was calculated as .041. This low natural mortality for mature walleyes is probably the most interesting finding of this investigation, for much present-day fish management practice is based on the premise that there is a relatively high loss of adult fish each year from natural causes. However, the fact that almost 80 percent of the walleyes marked in 1955 were actually counted in subsequent angler or gill net catches, or observed present in th 1957 spawning run two years after marking, substantiates this finding.

RATES OF EXPLOITATION

The annual rate of exploitation of a sport fishery can be expressed as that fraction of the population present at the beginning of the season which is harvested by anglers during the year. Estimates of the rate of exploitation are obtained from return of marked fish known to be present at the beginning of the angling season.

The fraction of marked fish returned in 1955 was: $276/1039 = .267$, the rate of exploitation for the 1955 season. In 1956, anglers returned 448 of 1,369 walleyes marked in 1956 for a rate of exploitation of .327. From a return of 330 of 1,581 walleyes bearing the 1957 mark, the rate of exploitation was estimated at .209 for the 1957 season.

An average rate of exploitation for marked fish of .268 for the 3-year period is believed to closely describe the annual walleye harvest but is considered as a minimum estimate since most of the possible errors tend to make the determination too low.

POPULATION ESTIMATES

Population estimates are based on the Petersen method. The population size of walleyes four years old and older (and which are considered to be completely acceptable to the angler) was calculated for each year. Populations of 3-annulus fish were estimated separately and correction made for incomplete acceptance of this group by anglers.

The anglers' catch in 1955 was 3,402 walleyes (Table 3). Walleyes, four years old and older, comprised an estimated 62.8 percent of the catch or 2,137 fish. Anglers returned 276 of 1,039 marked walleyes during the 1955 angling season. Using the Petersen ratio:

$$P = \frac{(1039)\ (2137)}{276} = 8{,}045,$$

the population of walleyes four years old or older at the beginning of the 1955 angling season. Calculation of the size of age-class III in 1955, included an adjustment for an estimated 90 percent acceptability of III's by

TABLE 3.—*Age-class structure of the angling catch of walleyes from Many Point Lake during the 1955, 1956, and 1957 angling seasons.*

[Percentage composition is in parentheses.]

Year	Size of sample	Size of sub-sample	Number in age class				Total catch
			II	III	IV	V and older	
1955	404	404	428 (12.6)	837 (24.6)	708 (20.8)	1429 (42.0)	3402 (100.0)
1956	1739	420	373 (7.5)	2003 (40.3)	712 (14.3)	1885 (37.9)	4973 (100.0)
1957	2106	375	95 (2.5)	1516 (40.6)	1050 (28.2)	1069 (28.6)	3730 (99.9)

anglers. The size of age-class III in 1955 was calculated as

$$\frac{(837/.9)\ (1039)}{276} = 3{,}501$$

walleyes, and the estimated total population three years old and older was 8,045 + 3,501 = 11,546 walleyes at the beginning of the 1955 angling season.

Population estimates for 1956 and 1957 were calculated by the same method. In 1956 anglers harvested an estimated 2,597 walleyes four years old and older and returned 448 of 1,369 walleyes bearing the 1956 mark.

Using the Petersen ratio the population, four years old and older, was calculated as 7,936 walleyes. From an estimated catch of 2,003 walleyes in age-class III, the population of III's in 1956 was calculated as 6,739 wall-walleyes. The total population of fish three years old and older was therefore 14,675 walleyes at the beginning of the 1956 angling season.

In 1957 anglers caught an estimated 2,119 walleyes four years old and older and returned 330 of 1,581 walleyes bearing the 1957 mark. Using the Petersen ratio the population was calculated as 10,152 walleyes four years old and older. The size of age class III in 1957 was calculated as 8,068 walleyes on the basis of an estimated 1,516 three-year-old walleyes in the anglers' catch. The estimated population of walleyes three years old and older was 18,220 at the beginning of the 1957 angling season.

The estimated population of walleyes three years old and older increased by 58 percent in the two-year period from the spring of 1955 to the spring of 1957, even though anglers harvested 8,375 walleyes during this time. It should be pointed out, however, that during the period of investigation two very strong year classes entered the fishery, resulting in what is probably a natural short term period of increased recruitment. Another investigation at some future date may well show a corresponding population decrease due to inadequate recruitment. However, recruitment alone cannot be used as the sole criterion for determining whether the rate of exploitation is at an optimum level for realizing maximum sustained yield in pounds. Such determination must also include consideration of the effects of changes in recruitment and rate of exploitation on natural mortality and fish growth.

Walleye Growth in Many Point Lake

Estimates of the annual growth of mature male and female walleyes were obtained empirically from measurements of marked fish recaptured in subsequent spawning runs. Growth of individual fish could not be traced, but it was possible to compare the average length of each group of marked fish one and two years after marking (Table 4). The average weights applied to walleyes in the spawning run are not those of gravid fish, but are weights calculated from the length-weight relationship of 886 walleyes returned by

TABLE 4.—*Average growth of marked walleyes recaptured in subsequent spawning runs one and two years after marking.*

Sex	Year marked	Length, weight and increment	Year recaptured		
			1955	1956	1957
Males	1955	Average length (inches)	17.2	17.8	18.3
		Length increment		0.6	0.5
		Average weight (ounces)	25.6	27.5	30.0
		Weight increment		1.9	2.5
	1956	Average length (inches)		17.1	18.0
		Length increment			0.9
		Average weight (ounces)		24.6	27.7
		Weight increment			3.1
Females	1955	Average length (inches)	21.2	22.3	23.5
		Length increment		1.1	1.2
		Average weight (ounces)	48.8	57.0	66.0
		Weight increment		8.2	9.0
	1956	Average length (inches)		20.8	22.4
		Length increment			1.6
		Average weight (ounces)		46.8	55.2
		Weight increment			8.4

anglers in 1956 (Fig. 4). Marked males increased an average of 0.7 inches in total length annually and 2.5 ounces in average weight. The average length of females increased 1.3 inches annually and the average weight increment was 8.2 ounces.

Average calculated length at each annulus for ages I through VII, was determined from scale samples from the anglers catch (Table 5). Annuli were well defined through four years of age, but age determination became progressively more difficult with the older fish. Growth computations beyond the seventh annulus are not included because of difficulty in identifying annuli. The average annual weight increment for ages I through III is 2.8 ounces. During the next four years of life (ages IV through VII) the average annual increment in weight is 7.6 ounces. In view of this increased weight increment rate after three years of age and the low estimated expectation of death from natural causes of .041, it appears possible that harvesting walleyes before they reach four years of age may prevent realization of maximum sustained yield in pounds, and may result in a sacrifice of quality of fish to obtain a harvest of greater numbers. It should be noted, however, that the increased growth rate after three years of age is probably due largely to increased growth of female fish and any size limit imposed on this fishery would tend to increase survival of slower growing males more than the faster growing female walleyes.

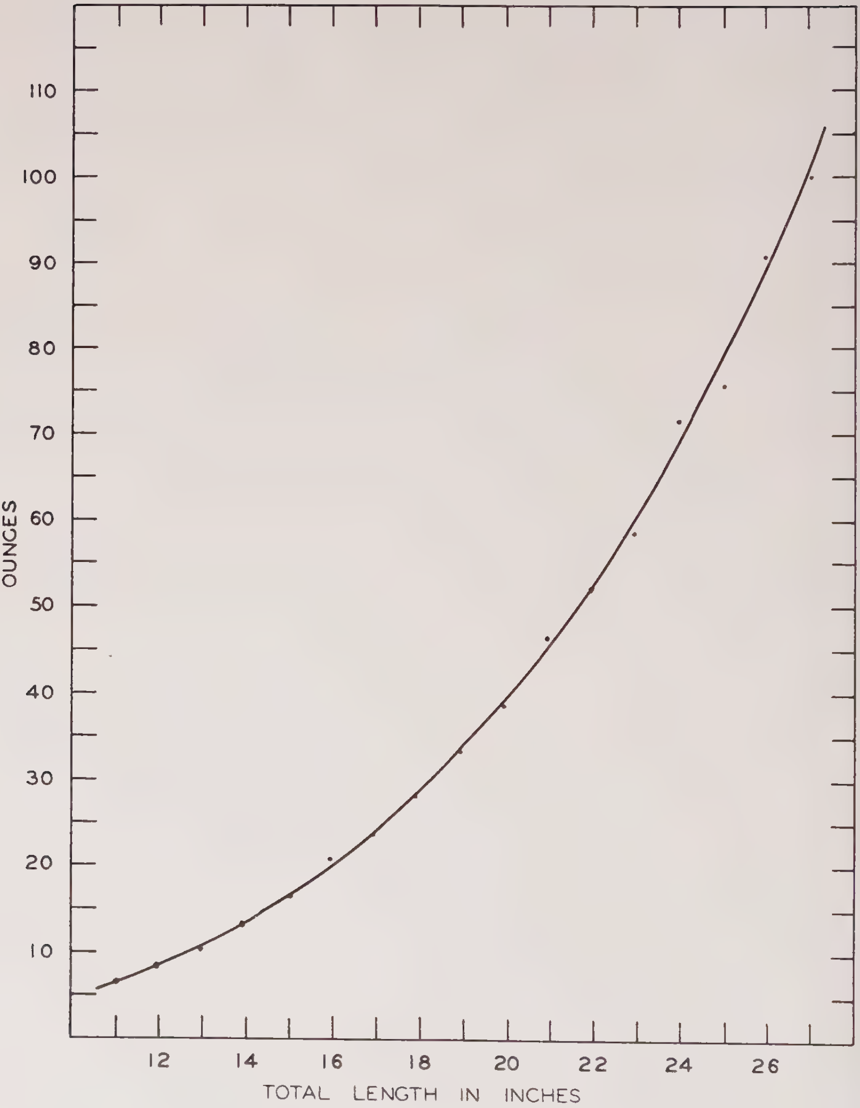

FIGURE 4.—Length-weight relationship of Many Point Lake Walleyes based on measurements of 886 walleyes caught by anglers during the summer of 1956.

Table 5.—*Average calculated length, weight and growth increment at each annulus of walleyes from Many Point Lake, Minnesota.*

Age class	I	II	III	IV	V	VI	VII
Length in inches	5.0	8.6	12.2	14.8	16.9	18.5	20.0
Length increment	5.0	3.6	3.6	2.6	2.1	1.6	1.5
Weight in ounces	1.0	3.5	8.5	16.0	23.0	30.5	39.0
Weight increment	1.0	2.5	5.0	7.5	7.0	7.5	8.5

ANNUAL AND TOTAL HARVEST

Fishing pressure was quite constant for the 1955 and 1956 angling seasons with 31,646 man-hours in 1955 and 30,628 man-hours in 1956 (Table 6). In 1957, the total man-hours dropped by about 18 percent to 25,042. Anglers harvested 38,857 pounds of fish of all species combined during the three-year period. Of this total 13,916 pounds were taken in 1955, 13,712 pounds in 1956 and 11,299 pounds in 1957. This is an average annual harvest of 7.5 pounds of fish per surface acre of water. This harvest cannot be considered large in the light of harvest information from some other Minnesota lakes (Moyle and Franklin, 1957). Oxygen depletion in a large portion of the deeper waters of the lake each summer, along with probable underutilization of all species other than walleyes and northern pike, accounts for the somewhat low total harvest in terms of pounds per acre.

More than 90 percent of the angling effort at Many Point Lake is directed toward catching walleyes and northern pike. Combined harvest of these species was 23,253 pounds or about 60 percent of the total weight of fishes taken during the three years.

The annual harvest of rock bass and perch does not reflect population size nor catchability of these species, but is governed primarily by anglers willingness to keep them. Anglers acceptance of rock bass and perch is at least partially determined by the quality of walleye angling. During 1955, when walleye angling success was low, anglers were more willing to keep these less desirable species.

A small annual catch of bullheads, sunfish, crappies and black bass is associated with relatively small populations of these species and is also influenced by their low vulnerability to the fishing methods generally used. Trolling, drifting and still-fishing with live minnows are the most common fishing methods.

The walleye catch increased from 3,402 walleyes weighing 4,826 pounds in 1955, to 4,973 walleyes weighing 6,292 pounds in 1956 and declined in 1957 to 3,730 walleyes weighing 4,215 pounds. The increased catch in 1956 over 1955 resulted from two factors: (1) the large 1953 years class was only slightly acceptable because of their small size in 1955, but were

TABLE 6.—*Total angling catch by species, as numbers and pounds, during the 1955, 1956 and 1957 angling seasons.*

Species	1955 Fishing season (31,646 man-hours)				1956 Fishing season (30,628 man-hours)				1957 Fishing season (25,042 man-hours)			
	No. of fish	Lbs. of fish	No. per man-hr.	Lbs. per acre	No. of fish	Lbs. of fish	No. per man-hr.	Lbs. per acre	No. of fish	Lbs. of fish	No. per man-hr.	Lbs. per acre
Bullhead	154	193	Trace	0.1	212	333	.01	0.2	182	255	.01	0.2
Northern pike	1259	2860	.04	1.7	1110	2642	.04	1.5	1126	2418	.04	1.4
Walleye Pike	3402	4826	.11	2.8	4973	6292	.16	3.7	3730	4215	.15	2.5
Perch	4858	1147	.15	0.7	3301	792	.11	0.5	3960	950	.16	0.6
Rock bass	7708	4684	.24	2.7	5395	3510	.17	2.0	4968	3225	.20	1.9
Sunfish	315	158	.01	0.1	174	83	.01	Trace	199	90	.01	Trace
Black crappie	18	18	Trace	Trace	10	16	Trace	Trace	25	32	Trace	Trace
Largemouth bass	17	27	Trace	Trace	12	36	Trace	Trace	25	40	Trace	Trace
Smallmouth bass	2	3	Trace	Trace	5	8	Trace	Trace	2	4	Trace	Trace
All Species	17,733	13,916	.56	8.1	15,199	13,712	.50	8.0	14,217	11,229	.57	6.5

nearly completely acceptable in 1956, and (2) an increase in the catchability of walleyes in 1956 as indicated by an increased rate of exploitation (from .267 in 1955 to .327 in 1956) under similar fishing effort.

Although the population of 'catchable size' walleyes was greatest in 1957 the total walleye catch declined. An 18 percent decrease in fishing effort along with decreased catchability contributed to the lower harvest in that year.

In the walleye fishery of Many Point Lake, there appears to be a direct relationship between population density and angling success. However, angling success may also be considerably influenced by little-known factors that cause fish to bite more readily in some years than in others. The walleye catch per man-hour increased with a population increase from 0.11 walleyes per man-hour in 1955 to 0.16 walleyes per man-hour in 1956. With highest population density in 1957, angling success (0.15 walleye per man-hours) was greater than that of 1955 but slightly less than success in 1956, indicating that walleyes were most vulnerable to the hook in 1956. An attempt to associate fishing success with weather data and water turbidity showed no correlations.

DYNAMICS OF THE WALLEYE FISHERY

Knowledge of the total harvest and rate of exploitation is of particular interest when related to mortality from natural causes and the growth characteristic of the population. In this section, the vital statistics of the Many Point Lake walleye fishery are applied to a theoretical fishery in which the population is stabilized and recruitment equals total mortality from day to day. This is a "Type IIA Fishery" as designated by Ricker (1944).

The reliability of information obtained from this approach depends not only on the accuracy of the fishery statistics used, but also on the compatability of these statistics with the assumptions upon which the mathematical model is based. In a "Type IIA Fishery", it is assumed that recruitment and natural mortality are proportionate to population size and occur at a uniform rate throughout the year. The actual situation at Many Point Lake, approaches the conditions assumed for the model if the summer angling season is considered as a year in the fishery, since both growth and fishing mortality take place primarily during the months of open water. Natural mortality probably occurs throughout the entire year, but since natural mortality is quite small, error from this discrepancy can not be great.

The mathematical model used is strictly applicable only to a stabilized fishery. This is not true for the Many Point fishery nor is it likely to be entirely true for a fishery of any natural fish population. This assumption would be partially satisfied if the average statistics obtained during the three-year investigation can be considered to describe the "steady population" within a natural range of fluctuation. More years of investigation at Many Point Lake are needed to fully satisfy this assumption.

Probably the greatest limitation to the practical application of this model is the possibilities for changes in growth, recruitment and natural mortality that may occur with changes in the rate of exploitation. Until such interrelationships are more thoroughly understood it appears that conclusions drawn from use of such mathematical models must be somewhat uncertain.

Presentation in detail the derivations of the relationships used is not within the scope of this paper. The reader is referred to Ricker (1944 and 1948) for description and sources of the mathematical procedure.

In a stabilized fishery, the gain in weight from recruitment (W), plus the growth in weight (G), must equal the loss in weight from fishing mortality (FM) plus the loss from natural causes (NM) if the "steady population" (S) is to remain constant. This is described by the equation of Russell (1939):

$$S + (G + W) - (FM + NM) = S$$

The steady weight of the population (S), times the instantaneous mortality rate (i), equals the annual loss in weight from the fishery (Si). Growth equals Sk, where k is the instantaneous growth rate. Recruitment (W) equals Si — Sk and

$$S = \frac{W}{i\text{-}k} \qquad (1)$$

Total mortality in weight is expressed by (i) times the steady weight of the population. Multiplying equation (1) by i, total mortality is;

$$\frac{Wi}{i - k} \qquad (2)$$

The instantaneous loss from fishing (p), plus the instantaneous loss from natural causes (q), equals total instantaneous mortality (i), and the annual mortality from fishing (FM), equals

$$\frac{p}{i}$$

times the total annual mortality. Multiplying equation (2) by $\frac{p}{i}$:

$$FM = \frac{Wp}{i - k} \qquad (3)$$

Similarly, the annual mortality in weight is $\frac{q}{i}$ times equation (2) and is expressed by:

$$NM = \frac{Wq}{i - k} \qquad (4)$$

The average annual catch of walleyes (FM) during the three-year period was 5,111 pounds. Using the instantaneous rates of the Many Point fishery (Table 7) in the above equations, the equation for the stabilized fishery was calculated as:

$$S + (G + W) - (FM + NM) = S$$

Which in this case is:

$$15{,}949 + (3190 + 2705) - (5111 + 784) = 15{,}949 \text{ pounds.}$$

Ricker (1944) and Tester (1952) have plotted yields for theoretical fisheries at various combinations of natural and fishing mortality rates and with various types of growth. They point out that when growth in weight of a fished population is greater than loss in weight from natural mortality, maximum sustained yield in pounds will be obtained from a less intensive harvest. That is, fish can be more advantageously harvested at a larger average size. From application of the Many Point data to a mathematical model, it seems evident that gain from growth (3190 pounds) is greater than loss from natural mortality (784 pounds), which indicates that the Many Point walleye fishery is being harvested at a rate which is too intensive to realize maximum sustained yield in pounds. It appears that anglers could eventually realize a larger sustained yield in pounds and take fish of a larger average size at a lower rate of exploitation. However, such a potential increase in sustained yield in pounds is contingent upon whether or not the environment, including populations of other species, will allow

TABLE 7.—*Vital statistics of the Many Point Lake walleye fishery.*

Instantaneous mortality rates		
Total	i	.3696
From fishing	p	.3205
From natural causes	q	.0491
Annual expectation of death		
Total	a	.309
From fishing	μ	.268
From natural causes	ν	.041
Walleye growth		
Instantaneous growth rate[1]	k	.2

[1] Based on the average percentage increase in weight between ages III and VII.

walleye population expansion without increasing natural mortality or slowing the growth rate of walleyes. It seems possible that in Many Point an expansion in the walleye population might be made at the expense of other less desirable species. However, there is also the possibility that compensatory changes in growth and natural mortality would accompany a change in the rate of exploitation resulting in no change in sustained yield in pounds. In this case management could be based on preference of anglers for greater numbers of small fish or for fewer fish of a larger average size.

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RELATIONSHIP BETWEEN SECCHI DISC READINGS AND LIGHT PENETRATION IN LAKE HURON

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ABSTRACT

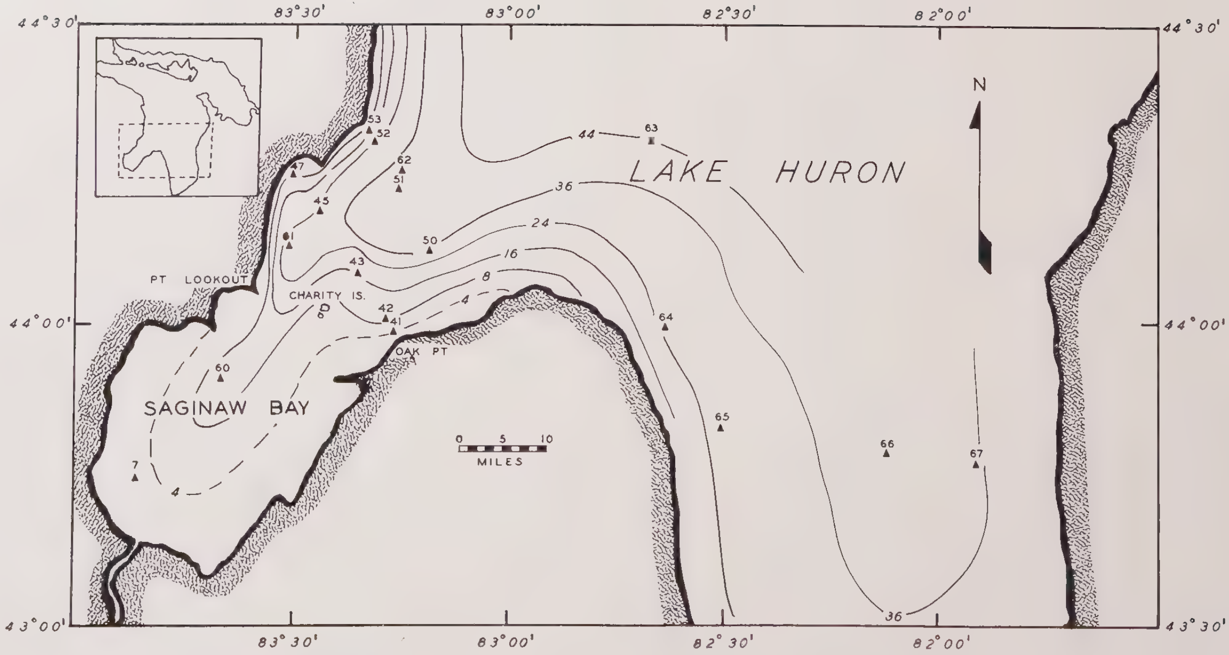
Fifty-seven paired photometer and Secchi disc measurements made at 18 stations in Saginaw Bay and Lake Huron support the view that a counterclockwise current usually occurs in the Bay with more transparent Lake Huron water flowing in along the northwest shore and less transparent Bay water flowing out along the southeast shore. The average percentage transmission of surface light intensity, at the Secchi disc depth, was 14.7 percent. Discrepancies in the relationship of disc readings to percentage transmission of surface light are related to the condition of the sky and sea. It is suggested that these discrepancies can best be explained on the basis of the spectral sensitivity of the human eye and its response to surface glare.

INTRODUCTION

The importance of light as an environmental factor can scarcely be overemphasized since it is the basis for almost all biological activity in water. The distribution and production of phytoplankton are directly related to the quantity of radiant energy penetrating the water. The abundance of phytoplankton in turn affects the distribution and production of zooplankton, and ultimately the production of fish. Light also directly influences the distribution of these organisms. In spite of its importance, very little information is available on the penetration of light into the waters of the Great Lakes. Some data have been published on Lake Erie (Parmenter, 1929; Chandler, 1942; Wright, 1955; Verduin, 1956), Lake Huron (Ayers, Anderson, Chandler, and Lauff, 1956), and Lake Michigan (Lauff, 1957). Only Chandler's study dealt with photometer measurements; the other studies were based on Secchi disc readings. For this reason, it was considered highly desirable to be able to interpret the value of Secchi disc readings in terms of light transmission.

FIELD PROCEDURE

Light-penetration measurements were made in June-September 1956 at 18 stations established in the operation of the U. S. Fish and Wildlife Service research vessel *Cisco* (Fig. 1) in Lake Huron and Saginaw Bay. Four stations were in the Bay and 14 in Lake Huron proper. These stations were visited at intervals throughout the summer and 57 paired photometer and Secchi disc readings were made.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N
LAKE HURON
44
63
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PT LOOKOUT
CHARITY IS.
42
41
64
OAK PT
44°00'
44°00'
60
SAGINAW BAY
65
66
67
0 5 10
MILES
7
4
36
43°00'
83°30'
83°00'
82°30'
82°00'
43°30'

FIGURE 1.—Saginaw Bay and the adjacent section of Lake Huron showing principal stations and average Secchi disc transparency (feet) June-August, 1956.

In this study Saginaw Bay water has been separated from Lake Huron water by a line extending from Point Lookout to Charity Island and from the island to Oak Point (Fig. 1). Chemical and physical data collected at hydrographic stations east of this line indicate that Lake Huron water enters the mouth of the Bay, whereas similar data from areas west of Charity Island indicate that conditions there approach those of an eutrophic lake. Data presented by Ayers *et al.*. (1956) also show that Lake Huron water extends into the mouth of the Bay.

Transparency measurements were made with a standard Secchi disc (diameter 20 centimeters) with black and white quadrants. Light-penetration measurements were made with a pair of 856YR Photronic photoelectric cells, matched for output and linearity, and a model 622 Weston microammeter. Surface light intensity was measured with one photoelectric cell and subsurface intensity with the other. This photometer was calibrated by the Engineering Research Institute, University of Michigan, so that readings of each cell could be converted to foot-candles. Field data were obtained by determining the greatest depth at which the Secchi disc was visible, and then measuring the light intensity at that depth and at the surface with the photometer.

Transparency measurements within a single area were similar throughout the period of study. Therefore, average readings for the entire summer at each station were used in drawing an isopleth map (Fig. 1) to illustrate the general situation. Either circulation is stable in this area in June-September or most of the measurements were made when similar currents existed. A limited number of transparency measurements by Ayers *et al.,* (1956) showed a comparable distribution.

TRANSPARENCY OF SAGINAW BAY WATER

It has been postulated that the circulation in Saginaw Bay is estuarine and that inflow occurs along the northwest shore and outflow along the southeast shore (Ayers *et al.,* 1956). The close agreement in the average disc readings at stations 7 and 41 (4 feet at both stations) supports the view that outflow takes place along the southeast shore. Similarly, the occurrence of clearer water at station 60, where all readings except one (10 feet) were 8 feet, indicates the penetration of Lake Huron water along the northwest shore into this region. Lake Huron and Saginaw Bay waters evidently flow together and mix in the vicinity of stations 42, 43, 47, and 61. At these stations the transparency varied considerably throughout the summer, ranging from 7 to 24 feet in July (average 16.8 feet) and from 9 to 32 feet during August (average 19.6 feet).

TRANSPARENCY OF LAKE HURON WATER

In the latter part of June and in mid-July, the Secchi disc readings averaged 29.3 and 29.5 feet, respectively, in open-lake area (range, 15 to

42 feet). Transparency increased notably at all open-lake stations in August, averaging 35.7 feet and ranging from 20 to 54 feet. A maximum disc reading of 54 feet was recorded at station 63. Low values (15 to 20 feet) in the open lake were frequently recorded from station 64. This exceptional situation may be due to a flow of Saginaw Bay water around the southeast shore into this area. Throughout the summer low transparency was also observed in north-shore waters at station 53 (5 to 13 feet).

COMPARISON OF SECCHI DISC AND PHOTOMETER READINGS

Photometer readings at the depth of the Secchi disc reading are expressed as percentage transmission of surface light. Secchi disc and photometer readings were made under various weather and sea conditions.

The average percentage transmission of surface light intensity, at the Secchi disc depth, was 14.7 percent, with a standard deviation of 3.95. This value compares favorably with those established by several other investigators. In the English Channel the Secchi disc disappeared from sight at a depth where the illumination was 15.8 percent of that at the surface (Poole and Atkins, 1929). Clarke (1941) published a value of 15.2 percent for the North Atlantic. Secchi disc readings have been found to be inversely proportional to attentuation coefficients which are about directly proportional to phytoplankton concentrations (Jones and Wils, 1956). Yoshimura (1938), using Birge and Juday's data, found that there was a linear relationship between the Secchi disc depth and the depth to which 5 percent of the surface light penetrated. The light penetration measurements were made with a pyrlimnometer, an instrument which is evidently less sensitive than photocells, since it recorded less light at Secchi disc depths than did the photocells.

The photometer measurements showed that more light was required to see the Secchi disc when the sea was calm than when the waves were gentle or choppy (Table 1). This relation held true regardless of sky conditions or the color characteristics of the water. The discrepancies were undoubtedly related to visual surface glare which was at a maximum when the sea was calm. Surface glare would cause the observer's pupils to contract, thereby

TABLE 1.—*Effect of state of sea on percentage transmission of light to maximum depth of visibility of Secchi disc.*

Sea	Number of observations	Percentage transmission	
		Average	Range
Calm	8	17.1	8.8–24.2
Gentle	36	14.9	8.5–22.6
Choppy	13	12.8	5.7–22.3
Total	57	14.7	5.7–24.2

limiting the amount of light entering his eyes and making it more difficult to see the Secchi disc. Surface glare had little or no influence, however, on the photometer measurements, since it has been shown that the surface loss of light, as measured by photocells, is substantially the same for smooth or rough surfaces when the sun has a zenith angle[1] of less than 50° (Davis, 1941). All measurements of this study were made when the zenith angle was less than 50°.

There was some evidence that the Secchi disc could be seen to a greater depth on clear days than on cloudy days, but differences in the measurements were slight. Consequently these data have not been included.

In the curve depicting the percentage transmission of light at the point of Secchi-disc extinction (Fig. 2), the shallowest readings were made in the Bay and the deepest in Lake Huron proper. Values falling between these extremes were mostly from areas where mixing of lake and bay water occurred. The trend in the curve is probably determined by the differences between the spectral sensitivity of the human eye and the photoelectric cell, and by the wave band of light that penetrated to the disc depth. Preliminary analysis of our light-penetration data indicates that green light (490 mu to 540 mu) penetrated to the greatest depth in Lake Huron, whereas yellow-orange light (590 mu to 610 mu) penetrated to a greater depth than green light in Saginaw Bay. Scattering of blue and green light was greater in the Bay than in Lake Huron because of the greater concentrations of suspended matter. The lower part of the curve (Fig. 2) shows that the Secchi disc could be seen at a depth to which a relatively small quantity of light penetrated in Lake Huron. Theoretically, the eye should discern the Secchi disc most easily in waters having a peak transmission of light with a wave-length of 550 mu, a value close to that of light penetrating the deeper areas of Lake Huron. Disc readings made in the Bay and especially in areas of mixing were low although the photometer indicated that more light was present than was required to see the disc at greater depths in the open lake. The human eye has less sensitivity to the yellow-orange light that penetrates into this water. The deflection of the upper part of the curve to the left is probably due to the increased ability of the observer to detect the disc at very shallow depths.

Sauberer (1939) also observed that there was a greater percentage of the surface light at the Secchi disc depth in turbid water than in clearer water. He explained this by postulating that the suspended material in turbid water caused a diffused light and an increase in the light scattered up from lower levels, consequently the Secchi disc could not be as easily seen. There is some doubt, however, as to whether light scattered up from below the disc is of any consequence.

Different individuals did not agree on disc readings at the same station. Discrepancies as great as 2 feet occurred between observations by different

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[1] The sun has a zenith angle of 0° when directly overhead.

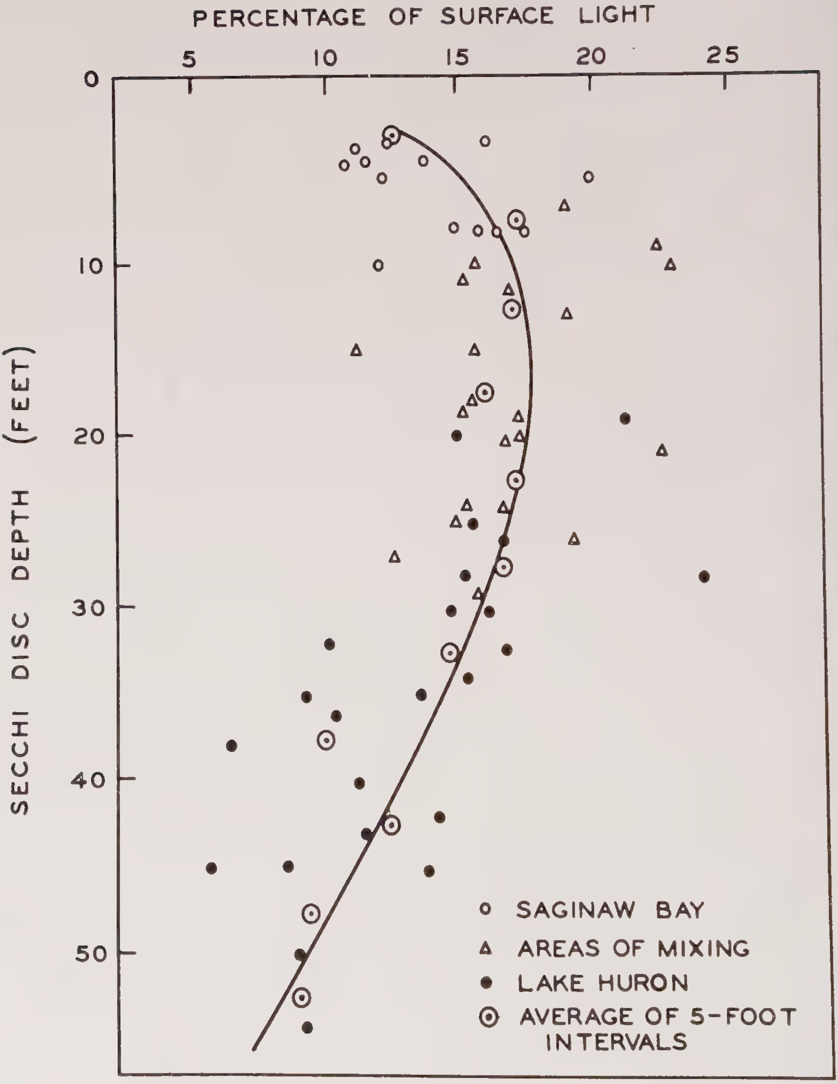

FIGURE 2.—Relationship of Secchi disc readings (feet) to percentage transmission of surface light at that depth.

individuals in clearer waters. For this reason the Secchi disc readings were made by the same observer with but few exceptions. Distance above the water surface was also a factor; usually the observer could see the disc at depths up to 2 feet deeper when he moved closer to the water surface. During this study most of the observations were made the same distance above the water. When the sky was not overcast observations were made on the shady side of the boat.

The influence that all these factors exert upon the accuracy of Secchi-disc measurements indicates the need to know more about this widely used tool. A more intensive study is desirable to ascertain more precisely what disc readings mean in terms of actual light penetration.

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UTILIZATION OF PLANKTON BY JUVENILE GIZZARD SHAD IN A SHALLOW PRAIRIE LAKE[1]

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Abstract

Irruptions of gizzard shad, *Dorosoma cepedianum* (Le Sueur), in North Twin Lake, Iowa in 1954 and 1955 provided opportunities for investigating certain basic ecological relationships of this species. Of the approximately 358 plankton species and varieties found in North Twin Lake, 260 were encountered in shad digestive tracts. On a volume basis, phytoplankton (primarily Cyanophyta and Chlorophyta) constituted the bulk of young-of-the-year and yearling gizzard shad food. Crustacean zooplankton were important food elements of recently hatched individuals.

Rotifers and crustaceans were about equally abundant in the plankton and in gizzard shad digestive tracts, and a fair degree of relationship was found between the amounts of green algae and diatoms ingested by age 0 shad and the proportions of the same forms in the plankton. Yearling gizzard shad apparently select green algae. Blue-green algae were apparently not consumed in proportion to their relative abundance in the environment. Where the relatively scarce *Microcystis aeruginosa* appeared to be a selected item, the most abundant plankter, *Aphanocapsa delicatissima,* constituted comparatively small portions of gizzard shad foregut contents. Gizzard shad are capable of consuming relatively minute plankters, some commonly ingested forms being no larger than 20 microns in greatest dimension.

Circumstantial evidence suggests that large shad populations may play a significant role in suppressing irruptions of objectionable algae. Where hatching periods overlap, feeding activities of newly hatched shad may adversely affect survival of the young game species through direct competition for crustacean plankton which both groups seem to require during early growth stages.

Introduction

In recent years the gizzard shad has attained widespread recognition as a nuisance fish. Unfortunately, very little factual information exists as to the direct (or indirect) effects shad populations may have on coexisting game and panfish. Irruptions of gizzard shad in North Twin Lake, Iowa in 1954 and 1955 prompted an attempt to define areas where possible competitive relationships between shad and desirable fishes might occur.

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A major portion of the present study was devoted to correlating plankton composition and abundance with the quality and quantity of plankton consumed by various fishes, particularly the abundant gizzard shad. Although only certain areas of the study proved to be directly concerned in elucidating shad-game fish relations, the complete picture of shad food relationships as uncovered in the present study is presented to supplement what little is known. One interesting aspect is the gizzard shad's possible role in suppressing populations of objectionable algae.

Few studies relating plankton populations to their utilization by fish have been attempted, but mention might be made of those on the Pacific sardine, *Sardinops caerulea* (Girard), by Lewis (1929) and the California Cooperative Sardine Research Program (1952); on young perch, *Perca fluviatilis* L., by Smyly (1952); and on young Atlantic shad, *Alosa sapidissima* (Wilson) by Maxfield (1953). Parr (1930) questioned whether some of the algae found in sardines (Lewis, 1929) really represented food.

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FISH SAMPLING PROCEDURE

An attempt was made to secure fish in such a manner that analyses of digestive tract contents would yield as true a picture as possible of the food and feeding habits of the fishes involved. Because of the shoaling behavior of young shad and of certain young game fishes, it was felt that little variation in the feeding habits of individual specimens comprising a given shoal would be expected. Hence emphasis was placed upon obtaining samples of fish falling into certain size or age groups at as many sampling periods as practicable during specified 24-hour periods rather than upon securing large unwieldy samples less frequently.

Representative samples of young-of-the-year and yearling shad, yellow bass, *Roccus mississippiensis* (Jordan and Eigenmann), and other species were obtained readily by seining in the littoral zone. The seine employed throughout the study was 30 feet in length and consisted of knotted $\frac{1}{2}$-inch (bar measure) mesh with $\frac{1}{4}$-inch mesh bag partially lined with nylon curtain material of approximately 1/16-inch mesh. Such gear was used successfully to capture very small gizzard shad (24 millimeters total length) and yellow bass (10 millimeters total length) as well as the fry of several other species.

Fish collections were made at various locations along the lake's perimeter with no particular pattern being followed as to areas sampled. Adequate samples[3] of small shad and other species could usually be secured within a 15-20 minute period at a given location. Such seining periods were begun every four hours on the hour throughout a 24-hour period. One complete 24-hour sampling run was made approximately every two weeks during the study (June-October, 1955).

Immediately following capture, all gizzard shad destined for digestive tract content analysis were pithed or allowed to suffocate and preserved in a 5-10 percent formalin solution. In contrast, young game and panfish were immediately refrigerated and held at a temperature just above the freezing point (33-35°F.) until their digestive tract contents could be examined. Such examination always took place within 24 hours after sampling.

PLANKTON SAMPLING PROCEDURE

As soon as a sufficient number of fish was collected from a given sampling area, a two-liter water sample was obtained in the immediate vicinity. Precautions were taken at all times to sample water outside the area recently disturbed by fish collection activities but yet as close as was practical to the point of capture of those fish that might have been feeding on its plankton components. Such samples were usually taken 40 to 50 feet from the shoreline and at a depth of from ½ to one foot, in water depths ranging from two to three feet. All samples were secured using a Kemmerer sampler except for several taken early in the study by merely submerging a 2½-liter wide-mouth bottle until filled to the 2-liter mark.

Immediately following its removal from the lake, the plankton content of each water sample was concentrated to about 15 millimeters by means of a Foerst continuous-flow centrifuge (1955 model: about 20,000 revolutions per minute). The rate of centrifuging was standardized at about one liter per eight minutes. Practically all plankton forms were very satisfactorily fixed by flooding the concentrate with a very hot formalin solution.

PLANKTON SAMPLE ANALYSES

The concentration and fixation methods described above and employed throughout the study proved to be quite efficient for sampling the nannoplankton which were of prime interest and for permitting identification of many motile forms which become distorted when preserved in the ordinary manner.

Plankton concentrates were measured numerically and volumetrically on a species or subspecies basis throughout. A detailed description and evaluation of the plankton measurement techniques employed have already been presented (Kutkuhn, 1958a). Briefly, the microplankton (primarily phytoplankton) were enumerated at 210X magnification employing a two-stage sampling scheme which involved "random" sampling of ocular micrometer "fields" from Sedgwick-Rafter cell mounts of the sample concentrates. For macroplankton (primarily zooplankton), an entire Sedgewick-Rafter cell mount constituted the sampling unit, counts in this case being made at 100X magnification. Volumetric contributions of the various plankters were determined using a "calculated volume" method wherein each plankter encountered during enumeration is measured in such a way as to permit its volume to be calculated. Volume estimates for each species in a given concentrate were then obtained and summed over all species to secure a grand total volume which served as a basis for calculating percentage contributions of each species.

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[3] Adequate from the standpoint of expenditure of labor in subsequent analyses and not necessarily from the statistical standpoint.

ANALYSIS OF FISH DIGESTIVE TRACT CONTENTS

Differences in diet and digestive tract anatomy of the gizzard shad and of the game and panfish species call for different methods of analyzing digestive tract contents. Primary considerations in such analyses are (1) the portion(s) of the digestive tract to be examined and (2) the analytical method itself.

In the case of the shad, it was pointed out earlier that a major objective of the present study was to determine, if possible, what small shad were feeding upon when captured and then compare such information with that relative to plankton abundance secured concomitantly. For such purposes, only the forepart of the shad's rather lengthy gut was considered when analyzing digestive tract contents. Arbitrarily included here were the pharyngeal pockets, esophagus, and gizzard. An exception of this rule was made in the rare event that these regions contained no "food" material in which case the contents of the duodenum (as defined by Wier and Churchill, 1945) were substituted for analysis.

Some consideration was given the advisability of including the pharyngeal pocket contents in the digestive tract analyses. Although Lagler and Kraatz (1945) presented histological evidence that would indicate a digestive rather than respiratory function for these organs, they did not entirely discount the possibility of the latter. It was theorized that the pharyngeal pockets may supply added pressure for the expulsion of water from the pharynx through the shad's closely spaced gill filaments and rakers. In this connection, it is interesting to note that Iwai (1954) also gave evidence to support the contention that the pharyngeal pocket apparatus in species closely related to the gizzard shad, *viz.*, the Japanese gizzard shad, *Konosirus punctatus* (Temminck and Schlegel) and the Pacific sardine, is accessory to the digestive rather than respiratory system. Kapoor (1957) came to a similar conclusion in regard to the pharyngeal pocket apparatus in another clupeoid species, *Gadusia chapra* (Ham.).

Bodola[4] found that pharyngeal pockets in gill-netted gizzard shad were often filled with food (?) and it was asserted that these organs were definitely associated with feeding. It is the author's opinion, however, that such occurrences were more likely the result of regurgitation so typical in gill-netted specimens rather than instances of food storage. In the present investigation, the pharyngeal pockets of seined specimens rarely contained measurable amounts of what might have been food material. Even though measurable amounts of plankton occurred in the pharyngeal pockets of less than 15 percent of the gizzard shad examined, the material was nevertheless included in all analyses. It was felt that such material represented substantial evidence as to what the specimens were feeding upon immediately preceding capture.

Very little difficulty was encountered in identifying organisms detected in any part of a gizzard shad's digestive tract. Possible qualitative and quantitative errors arising from an inability to remove consistently all ingested material from the verrucose and plicate lining of various parts of the digestive system were ever-present but are considered herein to have been minimal.

Since gizzard shad digestive tract contents are almost entirely composed of plankton organisms, it followed that their analysis could properly employ the same qualitative and quantitative methods described earlier for the plankton contained in the water samples. Thus the microplankton in the foreguts of shad comprising a given sample (grouped according to size) were estimated species-wise numerically and volumetrically employing the aforementioned two-stage sampling scheme. One milliliter aliquots were withdrawn from the diluted and thoroughly mixed digestive tract contents and placed in a Sedgwick-Rafter cell. Subsamples delineated by an ocular micrometer were then selected from the Sedgwick-Rafter cell mount in a "random" manner, the plankton counts and measurements obtained therefrom constituting, respectively, bases for subsequent numerical and volumetric estimates. Macroplankton numbers and volumes were estimated from counts and measurements made in entire Sedgwick-Rafter cell mounts. In contrast to the procedure followed in estimating macroplankton in the water samples, in which case three entire one-milliliter cell mounts from each sample concentrate were examined, only one cell mount was used for estimating the macroplankton composition of shad foreguts. On the basis of the author's earlier findings (Kutkuhn, 1958a), such a modification did not appreciably reduce the precision of macroplankton estimates but did materially reduce the amount of labor involved. Occasionally no dilution and associated subsampling was necessary and the entire foregut contents could be placed in a single cell mount and readily examined.

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[4] Bodola A: 1955. The life history of the gizzard shad, *Dorosoma cepedianum* (Le Sueur), in western Lake Erie. Ph.D. thesis, Ohio State University Library, Columbus, Ohio.

Digestive tract content analyses of juvenile (age group 0) game and panfishes differed somewhat from those for the gizzard shad. Here only the esophageal and stomachic contents were considered. Since the specimens were almost always examined in the fresh state soon after capture, there was not sufficient time before spoilage occurred to make adequate volume estimates of digestive tract contents employing the "calculated volume" method. It was necessary therefore to rely on the "frequency of occurrence" method as an index to an organism's importance as a food item. Notwithstanding this method's acknowledged disadvantages, it is felt that the data obtained are entirely sufficient for the comparisons discussed in later sections. In contrast to the many kinds and varying amounts of plankton ingested by small shad, the food of small game and panfishes was surprisingly consistent with regard to kinds and sizes of individual plankters taken (very rarely did more than three or four different forms occur in any one specimen) and seemed to be reasonably consistent in fish of a particular size from the standpoint of total volume. In very few cases did the total plankton content of the esophagus and stomach of an individual specimen exceed 0.1 cubic centimeters. Under these conditions it is felt that the frequency of occurrence method of food habit analysis can be a very useful tool.

PLANKTON FOOD OF THE GIZZARD SHAD: GENERAL CONSIDERATIONS

The present study places emphasis on ascertaining feeding relationships of young-of-the-year and yearling shad. It was felt that because of their much greater abundance, gizzard shad belonging to these age groups probably exerted a greater influence in the aquatic ecosystem than did older and markedly less abundant specimens. Unfortunately, the time required to analyze in detail digestive tract contents of individual specimens (from four to eight hours) precluded the examination of more than 30 young-of-the-year and 27 yearlings. It is believed, however, that because of the distribution of these specimens with respect to space and time, the continuous nature of the populations (with regard to age distribution) from which these specimens were sampled, and the apparent homogeneity of the prevailing aquatic environment, the data secured from these 57 shad give a reasonably accurate picture of shad feeding relationships during the study period. For comparative purposes, three two-year-old shad collected in late June were also subjected to foregut content analysis.

As was expected, little difference in the composition and quantity of foregut contents of shad in the same size group and comprising individual samples could be detected at any time during the investigation. Noticeable differences in food composition and volume for shad belonging to different size groups did occur frequently, however, emphasizing the advisability of segregating specimens into size or age groups and studying the data for each separately. Ages of all specimens were verified by the scale method of age determination.

Considered collectively, the foregut contents of the 60 juvenile gizzard shad collected during the period June 1 to October 31, 1955 comprised a wide assemblage of diverse organisms. Of approximately 358 eu- and tychoplankters known to occur in North Twin Lake (see Kutkuhn, 1958b for detailed breakdown), 260 or 73 percent were encountered at one time or another in shad digestive tracts (Table 1). Certain of these forms occurred rarely while most seemed to be more or less consistent in occurrence throughout the summer. Good correspondence between relative abundance in the environment and occurrence in shad digestive tracts was shown for some forms while others seemed to be consistently taken or by-passed regardless of their relative environmental densities.

Disregarding the data obtained for the three two year-olds, phytoplankton, qualitatively and quantitatively, were the major contributors to shad diets considered collectively during the study period (Table 1). Chlorophytes

TABLE 1.—*Collective summary of the plankton food of gizzard shad taken from North Twin Lake, Iowa: 1955.*

[Composition by major taxa expressed as percentage of total volume of ingested plankton.]

Age class	0	I	II	Number of species and varieties		Percent of total plankton volume
Size range (mm)	24–82	53–115	269–313	Detected in digestive tracts	Known to occur in lake	
Number of specimens	30[1]	27	3[2]			
Phytoplankton	72.6	81.7	13.3	189	236	84.3
Cyanophyta	20.1	41.7	12.0	26	35	30.9
Chlorophyta	22.3	23.6	0.2	77	93	15.7
Chrysophyta	18.8	12.2	0.1	56	62	32.5
Fungi	0.2	0.1	—	2	3	Trace
Protozoa (Mastigophora)	11.2	4.1	1.0	28	43	5.2
Zooplankton	27.4	18.3	86.7	71	122	15.7
Protozoa (Sarcodina and Ciliophora)	2.4	4.0	Trace	19	44	4.4
Rotatoria	4.6	6.0	0.4	34	49	8.6
Crustacea	20.4	7.1	86.3	14	20	2.6
Other	—	1.1	—	4	9	0.1
Amorphous material[3]	61	66	3			308

[1] The foregut of a single specimen contained no 'food' material.

[2] These specimens sampled in late June during a period of relatively high zooplankton abundance.

[3] Crude estimates expressed as percentage of total digestive tract contents.

or green algae (mainly members of the Chlorococcales) dominated from the qualitative standpoint while cyanophytes or blue-green algae were the major contributors volume-wise. Zooplankton constituted, on the average, about one-fourth of the total plankton volume encountered, crustaceans usually being the chief components. Of the major zooplankton taxa utilized, the Rotatoria were best represented species-wise.

An interesting aspect of the over-all shad diet was the high amount of amorphous material almost always present. Although this material included small stones and sand grains, the greater portion was usually of organic origin and similar in composition to the organic tripton observed in the plankton samples. Whether the latter actually constituted food material or was taken incidentally while grazing on living organisms is a question that remains unanswered.

RELATIONSHIPS BETWEEN FOOD AND FOOD SUPPLY AT THE FOOD TAXON LEVEL

Information such as that summarized in Table 1 is of interest only in a very general sense and can be misleading in the absence of more detailed supplementary data. A more detailed examination of relationships between each species concurrent status in the environment and in digestive tracts of the gizzard shad might be desirable but is impractical. Although relationships at the species level are masked, an alternative and simplified approach is to group all prey species into the taxa they comprise and subject the grouped data to a broad analysis. In the present study it was hoped that such treatment of the data would impart some idea of the gizzard shad's feeding tendencies with regard to utilization of forms comprising major taxa over a relatively long period of time.

Prior to examining the results of such an analysis, it might be well to reiterate the sampling procedure. All analyses were based upon volumetric estimates of prey organisms occurring in the plankton and of the same forms occurring as constituents of shad digestive tract contents. The paired environmental plankton and shad digestive tract data were subsequently plotted and subjected to regression analysis (Figure 1, Table 2). Since all analytical results were given as percentages, *i.e.,* percentage volumetric contribution of a given organism or group of organisms to the total plankton in the environment or in the digestive tracts, the data were first transformed ($y = \sin^{-1} \sqrt{x/_{100}}$, where x = percentage) to permit making the desired tests of significance.

As might be expected, relationships between the quantity of a given prey available and the quantity actually consumed were found to be, for all practical purposes, linear. In general, an increase in the proportion of a given taxon in the environment resulted in increased utilization of its members by gizzard shad. Exceptions were apparent in the case of protozoan

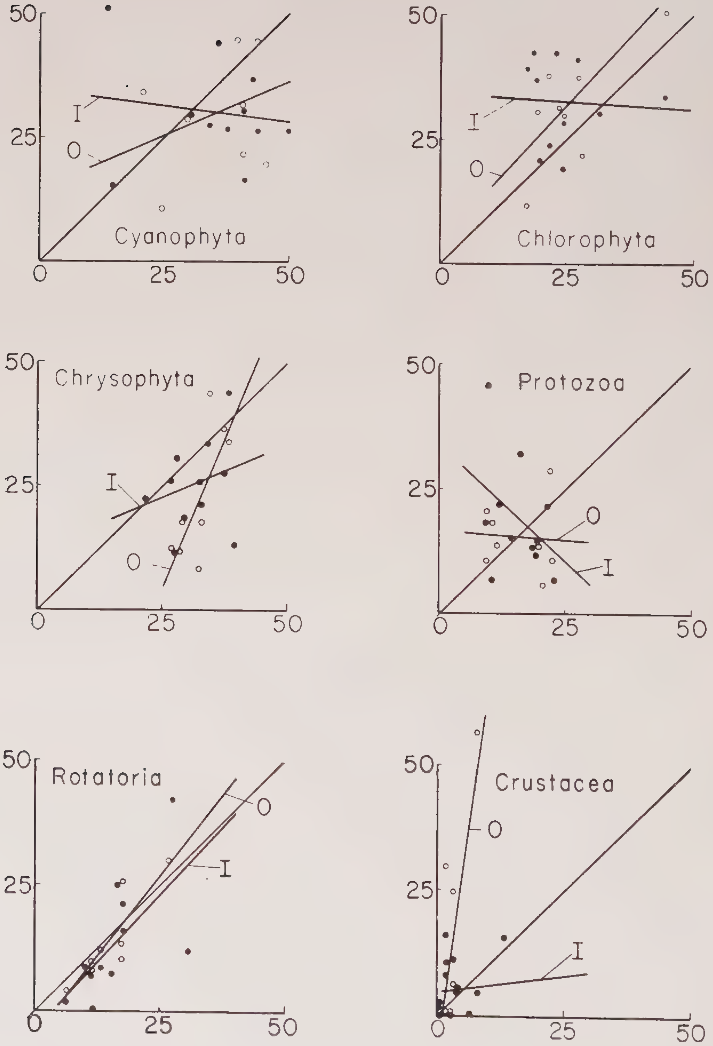

FIGURE 1.—Relationships between proportions (transformed percentages) of major taxa comprising the plankton (abscissa) and gizzard shad digestive tract contents (ordinate), both plankton and fish having been sampled concomitantly—North Twin Lake, Iowa: June-October 1955. ○—Age group O, ●—Age group I.

foods taken by shad of both age groups, and the blue-green and green algae food components of age I shad digestive tract contents (Figure 1.) In these instances a low level of prey abundance, for example, was not necessarily accompanied by diminished consumption of such forms. It should be pointed out, however, that because of the small sample size and the obviously high degree of dispersion in most cases, reasonably precise estimates of regression and correlation coefficients could not be obtained (Table 2.) Another disturbing although rarely occurring factor was that occasional fish in a given sample were found to have been feeding almost entirely on one kind of organism. The results of such an occurrence are obvious in Figure 1—Cyanophyta where the predominant food item in the foreguts of five yearly shad (collected July 9th and indicated by point in upper left hand corner) was *Anabaena circinalis.* Accompanying water samples revealed comparatively low populations of the same form in the general area from which the fish were collected. Such information provides reasonable evidence for inferring a somewhat high degree of selectivity for this organism on the part of the gizzard shad. Another possible explanation, however, might be that these fish were feeding in a local concentration of this alga.

In 5 of the 12 comparisons (Table 2) the abundance of the taxon in the digestive tracts of the gizzard shad was significantly (at the 95 percent confidence level) correlated with the abundance in the plankton. These 5

TABLE 2.—*Regression (b) and correlation (r) coefficients calculated from transformed data plotted in Figure 1. For shad of age groups 0 and I, n = 8 and n = 11, respectively.*

Taxon	Age group	b	S_b	t[1]	r
Cyanophyta	O	0.42 ± 0.96	0.391	1.48	0.40
	I	− 0.19 ± 0.68	0.302	3.94*	− 0.20
Chlorophyta	O	1.09 ± 0.74	0.302	0.30	0.83*
	I	− 0.07 ± 0.82	0.363	2.95*	− 0.06
Chrysophyta	O	2.43 ± 2.24	0.914	1.56	0.74*
	I	0.42 ± 1.17	0.518	1.12	0.26
Protozoa	O	− 0.07 ± 1.21	0.498	2.15	− 0.05
	I	− 0.91 ± 1.40	0.618	3.09*	− 0.44
Rotatoria	O	1.27 ± 0.71	0.290	0.93	0.87*
	I	1.09 ± 0.94	0.417	0.22	0.67*
Crustacea	O	7.34 ± 6.33	2.589	2.45*	0.76*
	I	0.87 ± 1.15	0.507	0.26	0.50

[1] $t = \frac{b-\beta}{S_b}$, where $\beta = 1$

*Statistically significant at the 95 percent confidence level;
$t_{.05}$ (d.f.=6) = 2.447 $t_{.05}$ (d.f.=9) = 2.262

were those for the Chlorophyta, Chrysophyta, Rotatoria, and Crustacea in the young-of-the-year gizzard shad and for the Rotatoria in the year-old shad. It is obvious (Figure 1) that as crustaceans increased in the plankton, they were utilized to a much greater extent by the young gizzard shad. The Rotatoria, on the other hand, increased in the diets in proportion to the increase in the plankton.

To check on the degree of departure from proportionality *(i.e.,* a one to one correspondence between the proportion of a given taxon in the environment and the proportion of the same taxon in the shad's food), the hypothesis that the regression coefficient $\beta = b = 1$ was tested for each set of transformed data (Table 2). Significantly high values for the test criterion (Student's "t") indicated departure from proportionality for the sample regression coefficients in four of the 12 sets. Three of these indicate that year-old gizzard shad showed little tendency to utilize more Cyanophyta, Chlorophyta, and Protozoa, as these increased in the plankton. The fourth indicates that young gizzard shad showed a greater increase in utilization of crustaceans than might be expected from the increases in the plankton. For the blue-green algae considered collectively, a wide displacement of points (exhibiting no consistent pattern as evidenced by low r values) resulted from an apparent high degree of "selectivity" upon occasion together with more frequent cases of "under-utilization" on the part of shad in both age groups but more particularly in the larger specimens. The main factor here seemed not so much the degree to which all blue-greens were utilized but the degree to which specific forms were taken. It will be pointed out later that while *Microcystis* and *Anabaena* were apparently selected items, other more abundant blue-greens were by-passed. Green algae were consumed fairly consistently ($r = 0.83$) in proportion to their abundance by age 0 shad but not by age I specimens where an irregular pattern of apparent selectivity was noted.

Protozoans displayed little semblance of having been consumed in proportion to their abundance by shad of either age group. Furthermore, there was little indication of a consistent pattern of selectivity or under-utilization of these forms from a collective standpoint.

RELATIONSHIP BETWEEN FOOD AND FOOD SUPPLY AT THE FOOD SPECIES LEVEL

It is clear that any analysis of food-food supply relationships made at the taxon level of the food supply is necessarily biased by the fact that all species comprising a given taxon do not enter the shad's food in like fashion. This factor accounted for most of the widely dispersed points noted in Figure 1. Thus while a given taxon may have been composed of several to many species high or low in abundance but utilized proportionately, it may also have been concomitantly represented by one or two very abundant or scarce forms that were taken not at all or way out of proportion to their abundance. To obtain a more accurate picture, the obvious solution then would be to examine the relationship of food to food supply at the level of the individual species making up the gizzard shad's food. As suggested earlier, however, the great amount of data often evolved (*e.g.*, each plankton sample in the present study included an average of about 60 species) would be somewhat unwieldy.

As an alternative to the foregoing approach, 38 sets of paired food-food supply data were more or less selected at "random" from the great amount of amassed data and plotted in Figure 2. Wide departures from proportionality for species within a food taxon can be readily noted for the Cyanophyta. The most abundant plankter, *Aphanocapsa delicatissima*, was almost always ingested in very small quantity. *Microcystis aeruginosa*, rela-

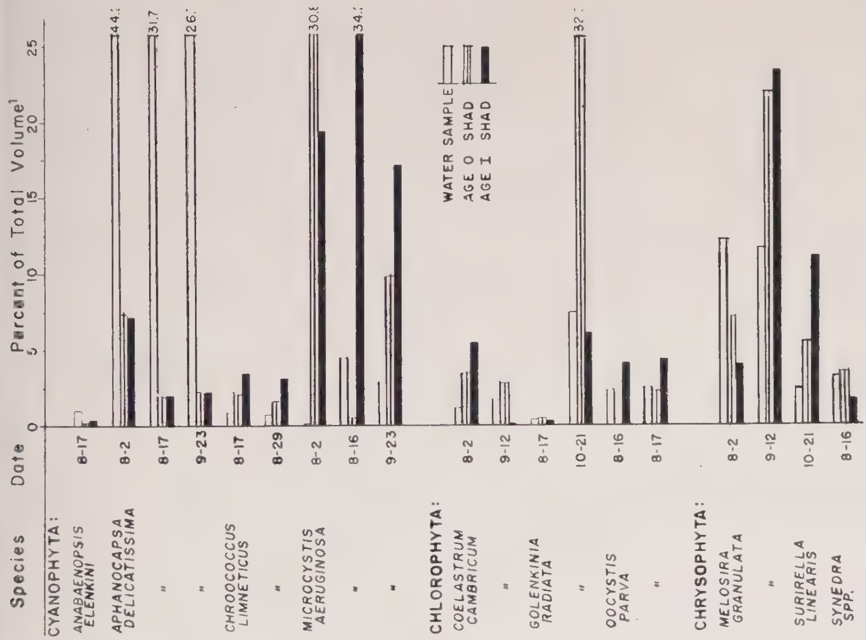

FIGURE 2.—Selected instances depicting relationships between the proportions of certain species occurring in the plankton and in the digestive tracts of gizzard shad representing two age groups, both plankton and fish having been sampled concomitantly.—North Twin Lake, Iowa: 1955.

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[1] Calculated on the basis of total phytoplankton volume in the case of all phytoplankters, and total zooplankton volume in the case of all zooplankters. See Table 1 for breakdown of these general categories.

tively scarce by comparison, constituted a major component of shad foregut contents. Other less common blue-greens such as *Anabaenopsis elenkinii* and *Chroococcus limneticus* seemed to be taken in accordance with their relative densities in the lake plankton sampled concurrently with the fish specimens (Fig. 2).

Although it is not too evident in Figure 2, there is a slight but further indication of a propensity for green algae on the part of shad in both age groups. In general, most green algae species seemed to be taken in proportion to their relative abundance. Occasionally, however, certain species appeared to fall into the "highly select" category such as was the case with *Golenkinia radiata* on October 21st. Most diatom species (Chrysophyta) were ingested in quantities not far out of proportion to their abundance as noted for those species depicted in Figure 2. Although the tendency seemed to be toward under-utilization of these forms (Figure 1), the examples given in Figure 2 would not tend to bear this out.

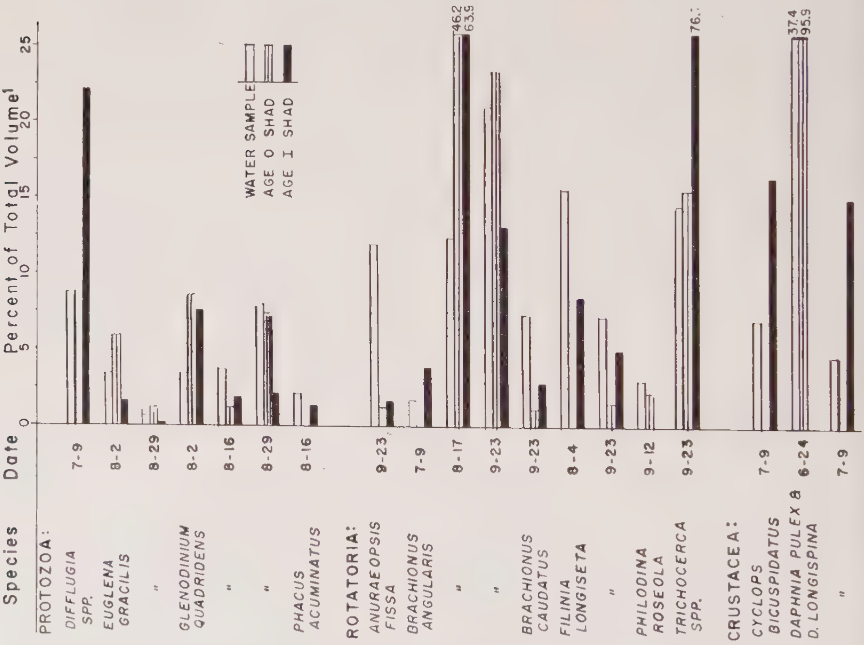

FIGURE 2 cont.—See preceding page.

Individual protozoan species for the most part were neither consistently sought-after nor by-passed but ciliates were rarely found in shad digestive tracts. The dinoflagellate, *Glendodinium quadridens,* was a good example of a protozoan phytoplankter which seemed to maintain nearly always a one to one correspondence volume-wise between its occurrence in the plankton and in shad digestive tracts.

Rotatorians presented the best examples of species being nearly always taken in amounts corresponding to their environmental densities. A notable exception occurred in the case of *Anuraeopsis fissa.* While often relatively abundant in the plankton, its volume in shad digestive tracts was consistently low.

Of the six principal taxa contributing to the shad's food supply, the plotted data in Figure 1 give a reasonably true picture of the juvenile shad's over-all propensity for species included in the Crustacea. In almost every instance, crustacean plankters were found to be select food items (see also Table 4). Of these, *Daphnia longispina* and *D. pulex* (usually occurring together) were the primary foods of very small shad and often constituted goodly portions of yearling shad food (Fig. 2). Other important forms included *Bosmina longirostris, Moina micrura,* and *Cyclops bicuspidatus.*

In summarizing this and the foregoing section, it is fairly evident that quantitative comparison of shad digestive tract content components with like components of the plankton is often misleading when carried out in a very general manner. Where prey organisms are considered only at higher taxonomic levels such as the Class or Order, actual food to food supply relationships may be masked. Although such was not generally the case in the present study, it is conceivable that within a higher classification, certain species might be by-passed and others selected by the predator organism. Both conditions would balance each other so that a collective analysis would imply that *all* members of that classification were being utilized proportionately in accordance with their relative abundance in the ecosystem. To obviate such a situation, emphasis must necessarily be placed upon examining predator-prey relationships at the species level of all organisms involved, notwithstanding any additional labor involved in the analysis.

SIZE OF FOOD ORGANISMS

The question of relative size of plankton organisms retained for consumption by gizzard shad seems to warrant some comment at this point since several statements relating to "selectivity" of fairly small forms have been made. It was determined during the present study that very small shad (the smallest examined were 24 millimeters in total length) utilize the largest zooplankton (e.g., *Daphnia longispina* and *Asplanchna priodonta)* and the digestive tracts of relatively large shad frequently contain measurable quantities of the smallest phytoplankton. Gizzard shad are commonly referred to as "filter-feeders". Their gill rakers apparently filter plankton organisms from the water as it is expelled from the pharynx over the gills. The propensity shown for some plankters in the present study suggests that shad may also pick out, perhaps individually, some of the larger plankters.

An explanation of why minute forms are almost consistently encountered among shad digestive tract contents is difficult to formulate. Probably the best explanation is that many small forms are ingested incidentally with larger organisms. Furthermore, the structure of many euplankters commonly found in shad digestive tracts is such that they may readily adhere to or form clumps with other plankters and thus enter the food in that manner. Minute phytoplankters possessing setae or spines such as *Golenkinia* spp., *Tetraëdron caudatum* var. *longispinum, Lagerheimia* spp., and *Franceia droescheri* are good examples.

To emphasize the fact that shad can retain very small items whether accidentally or purposively, Table 3 lists some minute phytoplankters commonly found in shad digestive tracts during the present study. Each organism is annotated with information as to its usual dimensions and with selected examples showing the comparative degree to which it occurred concurrently in the plankton and in shad digestive tracts.

Measurement of the gill structure of several shad revealed distances between the proximal ends of adjacent gill rakers in yearling gizzard shad to be as fine as 14 microns. Shortest distances between adjacent rakers of young-of-the-year specimens were of somewhat greater magnitude.

In general, it appeared that shad do not ordinarily consume large quantities of specific minute organisms. The important fact is that minute forms such as those listed in Table 3 may collectively constitute a significant portion if not the entire food of individual shad.

POSSIBLE SIGNIFICANCE OF THE GIZZARD SHAD'S UTILIZATION OF UNDESIRABLE ALGAE

On numerous occasions bluegreen algae have been so abundant as to be a nuisance at North Twin Lake. Attempts at chemical control during the years prior to 1954 were quite costly and resulted in only temporary relief. In 1954, however, only minor and temporary blooms occurred during the summer months and need for expensive control measures was at a minimum. Algal blooms were absent altogether in 1955 and so far as is known, no attempts at any sort of algae control were made. The relative clarity of North Twin Lake water during the 1954 and 1955 summers, due mainly to the absence of excessively large algae popoulations, was a condition favorably received by many lakeside residents as well as the general public. That the marked reduction in populations of objectionable algae in the lake during these summers might have been due to the feeding activities of the great numbers of shad present at these periods is worthy of consideration.

TABLE 3.—*Representative examples of relatively minute plankters frequently utilized by juvenile gizzard shad in North Twin Lake, Iowa: 1955*

Species	Size in microns	Selected instances showing degree of utilization		
		Date	Percent of total plankton volume	Percent of total digestive tract content volume
Cyanophyta:				
Aphanocapsa delicatissima	Spherical-sub-spherical colonies, variable but as small as 20 in diameter	8–2	18.9	1.9
Merismopedia tenuissima	Platelike colonies 16–18 wide	9–12	0.4	Trace
Chlorophyta:				
Crucigenia quadrata	Colonies to 25 broad	9–23	Trace	0.2
Golenkinia paucispina	Solitary cells 15–18 in diameter; setae 12–18 long	9–23	0.7	22.1
Oocystis parva	Colonies mostly less than 30 in diameter	8–15	0.3	0.7
Scenedesmus abundans	4-celled platelike colonies 15–30 long, 7–12 broad	8–2	0.1[1]	0.4[1]
Tetraëdron caudatum var. *longispinum*	Solitary cells 8–18 in diameter; spines to 8 long	9–23	0.1	0.8
Tetrastrum staurogeniaeforme	Colonies 20–25 wide	10–21	0.5	0.2
Chrysophyta:				
Achnanthes spp.	Solitary cells less than 30 long		Not detected	Traces
Cyclotella meneghiniana	Solitary cells 10–30 in diameter	8–15	Trace	Trace
Protozoa:				
Glenodinium quadridens	Solitary cells 20–35 in diameter, 24–30 long	8–2	0.4	2.0
Phacus acuminatus var. *drezepolskii*	Solitary cells 10–15 in diameter, 21–24 long	8–15	0.2	1.9[2]

[1] Included small quantities of *Scenedesmus quadricauda*.
[2] Included small quantities of *Phacus acuminatus*.

Generally speaking, the most troublesome alga in North Twin Lake has been *Microcystis aeruginosa*. This form was the dominant component of the very objectionable blooms occurring during the 1951 and 1952 summers and at times constituted the major part of the total plankton. *Coelosphaerium naegelianum* seemed to be in constant association with *Microcystis* although it was not nearly as abundant. *Anabaena spiroides* and *Aphanizomenon flo-aquae* comprised comparatively small amounts of the plankton in the 1951, 1952 and 1953 samples which have been studied but very likely experienced considerable development at other periods.

Microcystis aeruginosa was frequently one of the chief phytoplankton constituents in digestive tract contents of shad collected in 1955. A definite selectiveness for Microcystis was apparent at all times. *Anabaena spiroides* was also a major shad food component during periods when it exhibited good development.

Without further investigation, one might be tempted to attribute the noticeable decline in objectionable blue-greens (especially *Microcystis)* to the apparent propensity for these forms as food by the shad which developed concurrently in great numbers. Such a conclusion must be made with several reservations, however. In the first place, the mere fact that the gizzard shad feed heavily on certain blue-green algae does not mean that the shad, even though abundant, would effectively suppress the algae. To evaluate such a situation we would need to know much more than we do now about the production rates of the algae and the rates at which these algae are consumed by the shad. Furthermore several studies have indicated that blue-greens (in general) and certain green algae are resistant to digestion by fish and shellfish (Velasquez 1939, Fish 1951, and Flint 1956).

The reasons why certain algae are more resistant to digestion than others are not clear. Velasquez (1939) suggested that selective digestion may be due to the formation of resistant resting spores by some algae while they are passing through the gut, thus allowing them to escape digestion. Another suggestion (also made by Fish 1951) is the inability of digestive enzymes to break down colonial mucilage and/or cell walls. The formation of extracellular products by certain algae which tend to inhibit enzymatic activity is yet another possibility. The important work of Fogg and Westlake (1955) may have significance in this connection. These workers experimentally determined that *Anabaena cylindrica* produces extra-cellular polypeptide which, in turn, forms complex compounds with ions of copper, zinc, phosphate, ferric iron, and certain organic substances. The relationship between the polypeptide and the cupric ion is of special interest since the resultant complex substance was found to materially reduce the toxic effects of the copper on the alga involved. That a similar situation may prevail as regards the digestive enzymes of fishes does not seem unreasonable.

Although the material in the anal region of the digestive tracts of several gizzard shad was examined during the present study, it was extremely difficult in many cases to determine whether a given item had or had not undergone digestion. Generally speaking, most diatoms seemed to have been digested since many empty frustules were encountered. Others, however, appeared to be intact. *Microcystis* and *Anabaena* usually appeared undisturbed except for a distinctly lighter than normal appearance of the cell contents in some cases. On several occasions, diverse forms such as *Bosmina longirostris, Phacus longicauda,* and *Euglena oxyuris* were encountered wholly intact in the region of the intestine just anterior to the anus. Since these forms were usually found in a digested condition in most shad examined, such observations indicate that there are times (even during the summer) when foods of any type may pass through the shad's gut relatively undisturbed.

In every instance, Rotatoria such as *Keratella cochlearis, Brachionus angularis, Trichocerca cylindrica, T. lata,* and *Filinia longiseta* were found to have undergone complete digestion since only empty loricae were encountered.

Though there is little doubt that relatively large quantities of *Microcystis* and *Anabaena* were consumed by North Twin Lake gizzard shad during 1954 and 1955, the question of how much of these forms was actually converted to shad flesh is a matter of conjecture. It is inconceivable, however, that a fish reliant on rather small items for its food should seemingly seek out and ingest goodly quantities of these algae just to have it pass through the gut unassimilated.

Relationships Between Gizzard Shad and Desirable Fish Species

Because of the many complexities involved, few studies have been attempted to delineate relationships between coexisting fish species (see Larkin 1956 for recent summary). Good examples of such studies include those undertaken to determine what effects populations of undesirable char, *Salvelinus alpinus* L., might have on the welfare of populations of esteemed brown trout, *Salmo trutta* L., in Scandinavian lakes (Schmidt-Nielsen 1939; Svärdson 1949); Nilsson 1955). On the North American Continent, Larkin and Smith (1954) investigated direct competitive relationships between the introduced redside shiner, *Richardsonius balteatus* (Richardson), and the established Kamloops trout, *Salmo gairdneri kamloops* Jordan, in a British Columbian lake. The general approach to the problem outlined in each of these studies entailed a broad qualitative and quantitative comparison of the foods utilized by each species, in conjunction with comparative investigations of each species' relative condition and growth. Since the waters in which most such studies were carried out did not usually contain more than just two fish species, the results could be interpreted with greater confidence than if complicated by the effects of additional species.

In highly productive lakes such as North Twin Lake, the presence of numerous fish species (at least 22 in the present case) renders the examination of all possible interactions a practical impossibility. For reasons of simplicity, the following discussion will center mainly upon certain relationships between those species that comprised the largest populations during the study period, *viz.,* the gizzard shad and the yellow bass. For supplementary purposes, additional data are given for four common but not abundant species sampled incidentally with the shad and bass. These are the yellow perch, *Perca flavescens* (Mitchill); black crappie, *Pomoxis nigromaculatus* (Le Sueur); northern bluegill, *Lepomis m. macrochirus* Rafinesque; and orange-spotted sunfish, *Lepomis humilis* (Girard).

A major purpose of the present study has been to ascertain, if possible, areas where significant interactions might occur between gizzard shad and more desirable species. Of primary interest in this connection is the apparent fact that from the standpoint of the types of food utilized, gizzard shad on the one hand, and desirable game and panfish species on the other, occupy quite different ecological niches throughout much of their lives. Gizzard shad rely to a great extent on the seemingly inexhaustible phytoplankton (and certain zooplankton) for their food (Table 1) while yellow bass and game and panfish species in general are insectivorous during much of their early life and piscivorous as adults (Kutkuhn 1955).

However, in spring and early summer and prior to divergence into their respective food niches, recently hatched gizzard shad and various game and panfish species concomitantly consume certain plankton Crustacea almost exclusively (Tables 4, 5, and 6). Such a situation gives rise to the question of whether a significant interaction or competitive relationship may exist at this period, especially as regards the potential effects superabundant shad populations may have on collective not-so-abundant populations of desirable species.

As currently defined (Odum 1953), competition between two species can only prevail when either one or the other is materially affected as regards its growth and survival. With our present research methods, it is extremely difficult, if not impossible, to ascertain whether such an event has actually taken place.

Systematic sampling of small North Twin Lake fishes in 1954 and 1955 indicated that hatches of gizzard shad far outweighed those of yellow bass and other less abundant species. Under such conditions it seems reasonable to conjecture that the great numbers of newly hatched shad in both years might have had a deleterious effect on the survival of the young of contemporaneous species since all appeared to have a definite inclination toward feeding upon the same zooplankton forms. The spawning periods for the various species are somewhat variable but they do overlap. Gizzard shad appeared to spawn much of the early summer in North Twin Lake. Species such as the walleye, *Stizostedion v. vitreum* (Mitchill), whose periods of eclosion precede that of the shad, very likely pass through the plankton-consuming stage before the young shad appear. The newly hatched of such species may, however, be subject to competitive pressures from yearling and older shad.

TABLE 1.– *Crustacean and other plankton consumed by gizzard shad taken from North Twin Lake, Iowa: 1955. Composition expressed as percentage of total volume of ingested plankton. Figures in parentheses denote frequency of occurrence.*

Date	6–24	6–24	7–9	8–2 to 4		8–15 to 17		8–29 to 10–21	
Age group	0	II	I	0	I	0	I	0	I
Total length (millimeters)	24–27	269–313	53–59	30–47	82–100	35–65	69–104	42–82	100–115
Number of specimens	6[1]	3	5	7	5	5	10	12	7
Crustacea	99.8 (5)	86.3 (3)	12.6 (5)	24.0 (7)	0.4 (3)	22.0 (4)	4.3 (6)	9.2 (4)	1.0 (4)
Bosmina longirostris	0.9 (1)	2.1 (3)	5.1 (5)	0.3 (1)	0.1 (2)	0.5 (2)	—	—	—
Ceriodaphnia quadrangula[2]	—	—	0.2 (3)	1.7 (4)	0.1 (1)	—	—	—	—
Cyclops bicuspidatus	—	2.0 (3)	3.6 (5)	5.0 (6)	—	0.2 (1)	0.4 (3)	—	—
Cypria sp. (Ostracoda)[3]	—	—	—	—	—	5.8 (1)	3.4 (3)	—	—
Daphnia longispina & *D. pulex*	95.8 (5)	80.7 (3)	3.3 (3)	16.1 (3)	—	—	—	—	—
Diaphanosoma brachyurum	—	T (1)	—	—	—	—	—	—	—
Diaptomus oregonensis	3.1 (1)	1.1 (3)	0.1 (1)	0.6 (1)	T (1)	—	0.4 (1)	—	—
Leydigia quadrangularis[3]	—	T (1)	—	—	—	—	—	—	—
Moina micrura	—	0.2 (1)	0.1 (3)	0.3 (2)	—	15.5 (3)	—	9.2 (2)	0.5 (2)
Nauplii	—	0.2 (3)	0.2 (5)	—	0.2 (3)	T (1)	0.1 (1)	T (2)	0.5 (2)
Rotatoria	0.1 (1)	0.4 (3)	4.3 (5)	1.8 (6)	10.3 (5)	19.5 (5)	7.2 (9)	3.3 (12)	3.4 (6)
Protozoa	T (1)	1.0 (3)	6.0 (5)	21.5 (5)	10.0 (5)	3.1 (4)	11.6 (10)	9.1 (12)	8.8 (7)
Chrysophyta	T (1)	0.1 (2)	5.2 (5)	8.5 (4)	19.8 (5)	7.9 (5)	9.0 (10)	33.9 (12)	30.9 (7)
Chlorophyta	T (1)	0.2 (2)	12.2 (5)	14.8 (6)	34.3 (5)	29.5 (5)	34.9 (10)	32.6 (12)	35.5 (7)
Cyanophyta	0.1 (4)	12.0 (3)	59.7 (5)	29.4 (6)	22.8 (5)	18.0 (5)	29.6 (10)	11.6 (12)	20.0 (7)
Other[4]	—	T (1)	T (1)	T (1)	2.4 (1)	—	3.4 (8)	0.3 (3)	0.4 (3)

[1] The foregut of a single specimen contained no 'food' material.

[2] Includes some *Ceriodaphnia pulchella*

[3] Not planktonic (occasionally tychoplanktonic), associated with substrate.

[4] Fungi, Bryozoa (statoblasts), Hydracarina, and Insecta (Collembola and Diptera larvae).

T—Trace (less than 0.1 percent).

While it cannot at present be proved that the large shad hatches of 1954 and 1955 had any suppressing effects on contemporaneous year classes of yellow bass and other desirable species, it should be pointed out that the strong 1953 yellow bass year class passed through its initial year when gizzard shad were scarce. In 1954 and 1955, when gizzard shad were abundant, there was comparatively poor survival of young yellow bass.

Another important aspect that must be considered when assessing over-all relationships between the shad and its contemporaries is predation. This raises the question as to the effectiveness of gizzard shad as a buffer species. If a situation existed wherein both young shad and young yellow bass were being utilized in proportion to their relative abundance, then the numbers of shad consumed may proportionately reduce the numbers of small bass eaten, assuming no change in the numbers of predators. On the other hand, should the proportion of shad preyed upon be in excess of the proportion of bass consumed, then the buffering effect would be of an even greater magnitude. It is significant to note that young gizzard shad and yellow bass were the only North Twin Lake forage species of consequence during 1953,

TABLE 5.—*Percent frequency of occurrence of crustacean plankton and other organisms in digestive tracts of young-of-the-year yellow bass taken from North Twin Lake, Iowa: June-October 1955.*

Total length (millimeters)	10–19	20–29	30–39	40–49	50–59	60–69	70–79	Total
Number of specimens	13	8	26	114	156	95	13	425
Number empty	2	0	4	40	32	10	1	89
Crustacea	100	100	77	64	60	63	83	68
Bosmina longirostris	—	13	23	5	—	1	—	4
Ceriodaphnia quadrangula	—	—	4	1	—	—	—	*
Cyclops bicuspidatus	36	63	77	60	53	58	67	58
Daphnia longispina[1]	36	75	46	—	2	2	25	10
Diaphanosoma brachyurum	18	38	—	—	—	—	—	1
Diaptomus oregonensis	27	100	54	7	25	21	50	25
Hyalella azteca[2]	—	—	—	4	12	13	—	9
Leptodora kindti	—	—	—	—	—	—	8	*
Leydigia quadrangularis[2]	—	—	31	7	5	16	—	10
Moina micrura	55	—	—	11	22	19	8	17
Ostracoda[2]	—	—	—	—	1	4	8	1
Rotatoria	9	25	1	1	—	—	—	1
Nematoda[2]	—	—	—	—	1	1	—	*
Invertebrate eggs	—	—	—	—	1	—	—	*
Algae (Bacillariophyceae)	—	—	—	—	—	2	—	*
Algae (*Stigeoclonium*)[2]	—	—	—	—	1	—	—	*
Hydracarina[2]	—	13	—	3	—	—	—	1
Araneida	—	—	—	1	7	20	17	9
Insecta	—	25	38	86	90	94	83	82
Fishes	—	—	4	—	—	—	—	*

* Occurred in only one or two specimens.

[1] Includes some *Daphnia pulex.*

[2] Not planktonic (occasionally tychoplanktonic), associated with substrate.

1954, and 1955 (Kutkuhn 1955). The results of systematic sampling carried out in 1954 and 1955 indicated that in the former year, young-of-the-year gizzard shad outnumbered young-of-the-year yellow bass in excess of 10 to 1. During the same period, shad prevailed as the chief forage species and comprised about 90 percent of the total volume of forage fish utilized, compared to approximately 8 percent for small yellow bass. In 1955, however, shad of forage size outnumbered young-of-the-year bass by only about 3 to 2 but still were consumed by predators in approximately the same amounts as the previous year. Observations such as the latter suggest that gizzard shad may be a more or less select prey at times when they are not comparatively abundant. There is the further possibility that the predator species involved may have acquired the habit of utilizing shad when they were more readily

TABLE 6.—*Percent frequency of occurrence of crustacean plankton and other organisms in digestive tracts of young-of-the-year yellow perch, black crappie, bluegill, and orange-spotted sunfish taken from North Twin Lake, Iowa: June-October 1955.*

Species Total length (millimeters)	Yellow perch 60–85	Black crappie 30–60	Bluegill 20–60	Orange-spotted sunfish 10–35
Number of specimens	85	35	40	139
Number empty	13	3	3	20
Crustacea	19	97	89	98
Bosmina longirostris	—	28	8	16
Cyclops bicuspidatus	18	94	89	84
Daphnia longispina[1]	—	—	—	1
Diaptomus oregonensis	—	16	3	9
Hyalella azteca[2]	1	—	—	—
Leydigia quadrangula[2]	—	16	5	6
Macrothrix laticornis	—	—	—	2
Moina micrura	—	56	13	78
Nauplii (Copepoda)	—	—	5	3
Ostracoda[2]	—	9	35	12
Scapholeberis mucronata	—	—	—	1
Rotatoria	—	40	13	34
Anuraeopsis fissa	—	40	—	6
Brachionus angularis & B. caudatus	—	—	8	28
B. quadridentata	—	—	—	8
Euchlanis dilatata	—	—	5	1
Notholca acuminata	—	—	—	2
Polyarthra vulgaris	—	—	—	1
Nematoda[2]	—	—	—	1
Algae (Bacillariophyceae)	—	—	8	—
Hydracarina[2]	15	16	30	13
Araneida	1	—	—	1
Insecta	99	59	89	34
Gastropoda	3	—	—	—
Oligochaeta	—	—	5	—
Fishes	—	62	—	—

[1] Includes some *Daphnia pulex*.

[2] Not planktonic (occasionally tychoplanktonic), associated with substrate.

available and continued even when such availability diminished. It is in such instances that the buffering qualities of the gizzard shad become readily apparent.

While it is impossible to make a very accurate over-all appraisal, it seems that any adverse effects of direct competition for food elicited by an abundant shad population during early developmental stages of desirable species may, in lakes such as North Twin Lake, be balanced by the buffering effect upon predation and by the forage the shad provide for game and panfishes at later growth stages.

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A METHOD OF DETERMINING THE SEX OF THE STRIPED BASS, *ROCCUS SAXATILIS* (WALBAUM)

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ABSTRACT

A method is described for sexing striped bass *Roccus saxatilis* (Walbaum) by use of a serrated-jaw ear forceps. The instrument is used to extract gonads from dead fish in samples of commercial catches, without incurring damage to the fish which affects the market quality. The gonads are examined later in the laboratory and are identified as male or female. The technique has proven satisfactory in large scale sampling of commercial catches.

INTRODUCTION

In a recent study of striped bass *Roccus saxatilis* (Walbaum) undertaken by the United States Fish and Wildlife Service, it became necessary to determine the sex ratio in North Carolina populations for adequate interpretation of data on population dynamics, fish movement, and spawning activity.

Raney (1952) and Merriman (1941) state that no valid way has been found to determine the sex of striped bass by the use of external characters and that the gonads must be inspected if differentiation is to be made. Workers in the past have sexed dead striped bass by examining their reproductive organs. Gonads were obtained by dressing fish for sportsmen, from fish being dressed in commercial fish houses (Merriman, 1941; and Morgan and Gerlach, 1950), and by purchasing fish especially for sex-ratio studies or for studies concerning reproductive cycles (Vladykov and Wallace, 1952). The sex of ripe fish, living or dead, can be readily determined since reproductive products are exuded upon application of digital pressure in the region of the genital pore. However, samples are rarely taken from a population, even on the spawning ground, in which all fish are fully ripe. Consequently a method of internal sexing is required even here.

Vladykov and Wallace (1952) found that the numerical relationship of males to females does not remain static through all seasons of the year. Therefore, a complete picture of the relationship of the sexes of striped bass requires sampling throughout the year in all regions occupied by a given population.

It is a common practice in North Carolina as in other states for striped bass to be marketed as whole fish. An internal sexing method was devised which is accurate and does not reduce the market value of the fish.

The author wishes to express his appreciation to the following: Messrs. William S. Davis and Robert D. Lewis who shared in the development of the technique; to the striped bass investigations staff of the U.S. Fishery Laboratory, Beaufort, North Carolina, for assistance in field testing and perfecting the method; and to fish dealers of the Albemarle Sound region of North Carolina, who cooperated so generously in supplying fish for our studies.

METHOD OF SEXING

After experimentation with several types of surgical instruments it was found that gonadal tissue could be extracted through the vent by use of ear forceps having serrated jaws.[1]

A thin blade knife or a scalpel is inserted in the vent and a slit is made through the dorsal wall of the intestine (Fig. 1). The closed forceps are then passed through the incision, opened, moved forward, and closed to grasp the gonad.

Once the gonad is grasped, a firm, constant pull is exerted on the forceps with one hand while the other hand is used to make short, lateral movements of the fish to break the membranes surrounding the gonads. At times a portion of the gonad is torn away and at other times, particularly in small fish, an entire testis or ovary is pulled free. The vent is not noticeably enlarged even after the removal of an entire, relatively large gonad. A fragment of gonadal material large enough to be identified as such in the field is sufficiently large for laboratory identification as to sex. Practice is required in locating gonads with the forceps, and in separating gonadal material from adipose and intestinal tissue which are also frequently withdrawn from the body cavity. It has been noted that fewest mistakes are made and greater speed is achieved when work is done with relatively small (9 to 15 inch) striped bass. Frequently tissue can be extracted with greater facility from fish over 20 inches in length by inserting the instrument directly into the genital pore, grasping the gonadal tissue, and extracting the material through the same opening. This is impractical in smaller fish because of the size of the genital pore which prohibits insertion of the instrument without mutilation of the fish. Thus far, forceps have not been used to sample gonads which are in other than the resting stage.

After extraction, each gonad or fragment thereof has been placed in a 4 milliliter vial containing 5 percent formalin and a coded label. Code numbers corresponding to those on scale envelopes upon which length, weight, date and location of capture, gear employed, and other pertinent data are recorded.

Later the sex of the tissue is determined in the laboratory by means of a binocular dissecting microscope. Identification in this manner presents no

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[1] The instrument was supplied by the American Hospital Supply Corporation, Atlanta Division, Chamblee, Georgia, and is cataloged as Hartman Ear Forceps, serrated jaw, item No. 330-25.

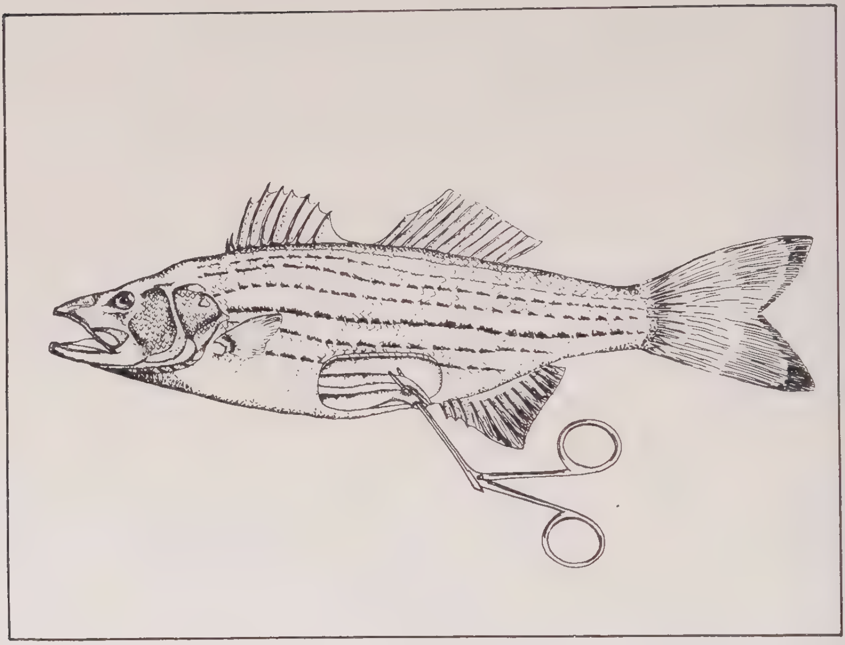

FIGURE 1.—Use of ear forceps in sexing striped bass. Forceps are inserted in vent and through intestinal wall to grasp gonad.

difficulty since the granular oocytes in ovarian tissue are readily distinguishable from the fine-textured spermatocytes.

Field examination of striped bass gonads showed that the tissue from testes is usually pale or whitish in appearance and that ovarian tissue is usually reddish and somewhat translucent. A sample of gonads was tentatively identified as male and female on the basis of appearance when sampled. Re-examination of this material in the laboratory showed that microspcopic examination of the gonads is necessary for 100 percent accuracy in distinguishing sexes from resting gonads.

The rapidity of sexing by this method varies considerably, depending upon the experience of the operator, the conditions under which he is working, and the size of the fish. One operator and a recording assistant sexed 125 striped bass in approximately three hours. In addition they took scales and measurements and recorded these data.

It is possible that this method may be applied to other species of fish in which determination of sex by external inspection is difficult or impossible and in which sex ratio studies are prerequisite to the solution of research problems.

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EFFECT OF REMOVAL OF PANFISH AND TRASHFISH BY FYKE NETS UPON FISH POPULATIONS OF SOME MASSACHUSETTS' PONDS

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Abstract

During the period 1951-56, 127,430 pounds of panfish and trashfish have been removed with fyke nets from 45 ponds in Massachusetts in an attempt to improve gamefish populations. Removal has ranged from less than one to 146 pounds per acre annually. Data from four ponds ranging in size from 20 to 269 acres are presented in detail. Where removal was intensive, growth rates of panfish increased markedly. Growth rates of gamefish, especially chain pickerel and largemouth black bass, which were returned to the water, showed a slight decrease or no change. Older panfish, remaining after thinning operations, showed less increase in growth rate than did younger fish spawned during or after the operations. No major changes in species composition in favor of gamefish were apparent. It is concluded that the fyke netting has increased growth rates of the species being thinned but has not materially improved gamefish populations.

Introduction

As an experimental management measure designed to improve gamefish populations of lakes and ponds, the Massachusetts Division of Fisheries and Game, during the period 1951-56 engaged in the selective removal of overabundant panfish and trashfish with fyke nets. Gamefish in these waters include chain pickerel *(Esox niger)*, largemouth back bass *(Micropterus salmoides)*, and smallmouth black bass *(M. dolomieu)*. Panfish are white perch *(Morone americana)*, yellow perch *(Perca flavescens)*, bluegill *(Lepomis macrochirus)*. black crappie*(Pomoxis nigromaculatus)*. and brown bullhead *(Ameiurus nebulosus)*. Trashfish are white sucker *(Catostomus commersoni)*, golden shiners *(Notemigonus crysoleucas)*, American eel *(Anguilla bostoniensis)*, and lake chubsucker *(Erimyzon sucetta)*.

In this program, it was assumed that: (1) removal of large portions of the overabundant panfish and trashfish populations would allow better opportunity for survival of gamefish because of decreased competition and predation and (2) increased growth rates of all species would result from a reduction of the non-gamefish populations. The present paper deals with evaluation of these assumptions.

Forty-five ponds, ranging in size from 20 to over 1100 acres, have been netted. Of these, 10 have been netted for two or more years, thus making preliminary evaluation of the effectiveness of the netting possible. A total of

127,430 pounds or 63.7 tons of panfish and trashfish were removed. Annual removal ranged from less than one to 146 pounds per acre in individual waters. Principal species removed were white perch, bluegills, yellow perch, bullheads, white suckers, black crappie, and golden shiners. Gamefish were returned to the water. Most netting was in the spring, but some was also carried out in the summer and fall.

The fyke nets used were of similar construction and size throughout the operation and were D-framed heart-lead bonneted wingnets. Leads were 100 feet and 200 feet long, 5 to 10 feet deep, and constructed of 2-inch stretch-measure webbing. Fyke trap pots were of 1½-inch stretch-measure webbing covering frames 5 feet 6 inches wide and 4 feet 6 inches high. Wings were 32 feet in length and 9 to 10 feet deep and made of 1½-inch mesh. Bonnets spanned 28 feet between the wings and were made of 1½-inch mesh.

In some ponds, copper sulphate was used to increase total catches (Tompkins and Bridges, 1955). Average daily catches in spring were about 50 pounds per net lift. Minimum size of fish taken was three to five inches in total length depending on body shape of the species involved. The maximum size of fish captured depended on occurrence within the pond.

Evaluation of this program is based on an analysis of age-and-growth data involving the back-calculation of 3,309 scale samples of game and panfish, length-frequency distributions of the principal species involved, and species composition of the net catches in all ponds netted more than once. The detailed information presented is for four lakes or ponds which may be considered typical. Two of the four, Indian Lake and Jordan Pond, were intensively netted for three years. One, Billington Sea, was thinned lightly for four years, and one, Duck Pond, was netted with moderate intensity for two years. Species compositions in the four lakes varied but all were characterized by an overabundance of panfish or trashfish and a paucity of gamefish. Three of these four lakes are located in the suburbs of large population centers and the other is a popular resort area. More detailed information on the physical and chemical characteristics of these waters is presented by Stroud, (1955), McCabe and Swartz, (1951), and McCabe, (1949).

INDIAN LAKE, WORCESTER

Indian Lake, Worcester, (172 acres), is a shallow, artificial impoundment having a maximum depth of 15 feet and an average depth of 8 feet. It has soft water, and is slightly basic to neutral in acidity. It is not thermally stratified during the summer months. A total of 19,310 pounds of panfish and trashfish were removed during 1954, 1955, and 1956. This amounted to 78.0, 16.5, and 14.4 pounds per acre for these respective years.

In the 1930's and 40's, Indian Lake was used as a source of white perch and other panfish for stocking other waters. Approximately 47,300 pounds of white perch (338,000 individuals) were removed in the 20 years prior to 1954. Yet, when intensive thinning operations were carried out in 1954,

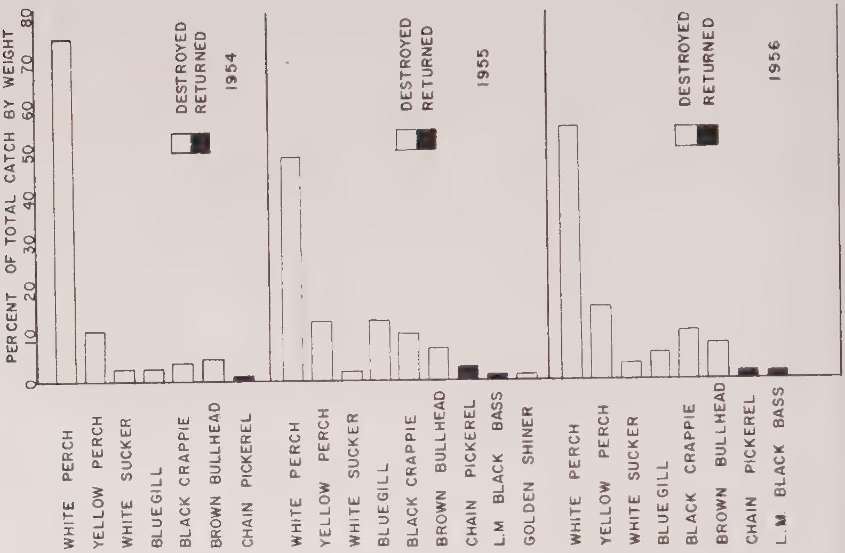

FIGURE 1.—Catch composition of fyke nets, Indian Lake, Worcester, Massachusetts, in 1954, 1955, and 1956.

a total of 13,846 pounds of fish were taken and destroyed, of which 75 percent were white perch (Figure 1). These fish averaged about six inches in total length and the 94 fish aged showed a mean age of five years. Very few of the white perch were large enough to be desirable to anglers. In the following year, 1955, about 50 percent of the total catch of 2,913 pounds were white perch. The 151 white perch aged had a mean age of three years and averaged about seven inches in length. By 1956, the mean age of the white perch sampled (112 fish) had decreased to less than three years and the average length increased to almost eight inches. About 55 percent of the 1956 total catch of 2,554 pounds were white perch, most of which were large enough to be desirable to fishermen. Thus, the growth rate of white perch increased markedly after two years of intensive netting (Figure 2). Essentially the same ratio of gamefish to other fish were taken in the nets in 1956, as in the initial operation in 1954, (Fig. 1).

Yellow perch and black crappie growth rates were also increased, although not as markedly as in the case of white perch (Figure 2). Growth of largemouth black bass and chain pickerel, the only species returned to the water, decreased slightly from 1954 to 1956 in spite of drastic thinning of what was believed to be their primary competing species.

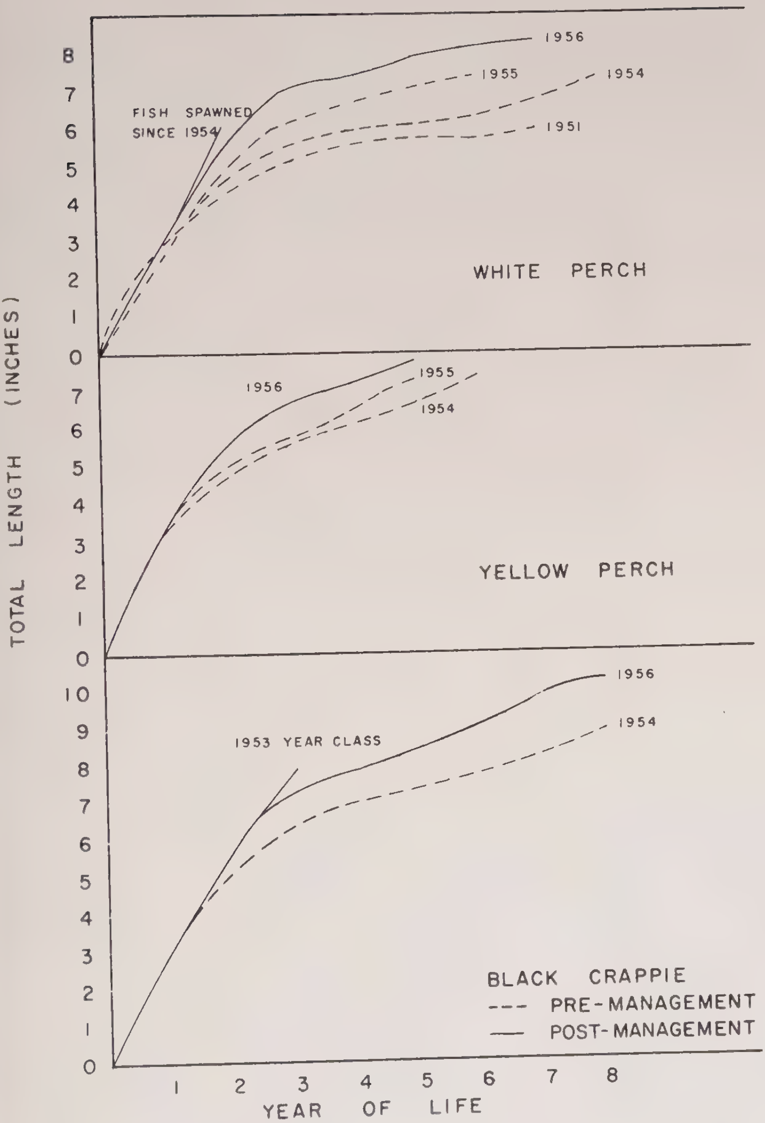

FIGURE 2.—Age-growth curves of Indian Lake white perch, yellow perch, and black crappie, by years of capture.

Billington Sea, Plymouth

Billington Sea, Plymouth (269 acres) is physically similar to Indian Lake. It has a maximum depth of 11 feet and an average depth of 7 feet. Here, netting intensity was much lighter. Removal was 4,190 pounds in 1952, 4,000 pounds in 1954, and 2,240 pounds in 1956. This was 15.0, 13.5, and 8.4 pounds per acre in these respective years.

Bluegills and white suckers constituted a major portion of the fish removed in each thinning operation, yet, as shown in Figure 3, their percentage representation in 1956 (50 percent) was approximately the same as at the start of the netting in 1952 (55 percent). The 1954 netting reflects a slight increase in percentage of smallmouth black bass over 1952. However, since 663 adult smallmouth black bass were stocked in 1952 after the netting, this increase may indicate this stocking rather than a result of the thinning operations. During the period considered, growth rate of white perch changed very little while the growth of yellow perch showed a decrease, especially after the third year of life. Chain pickerel growth remained constant from 1954 to 1956.

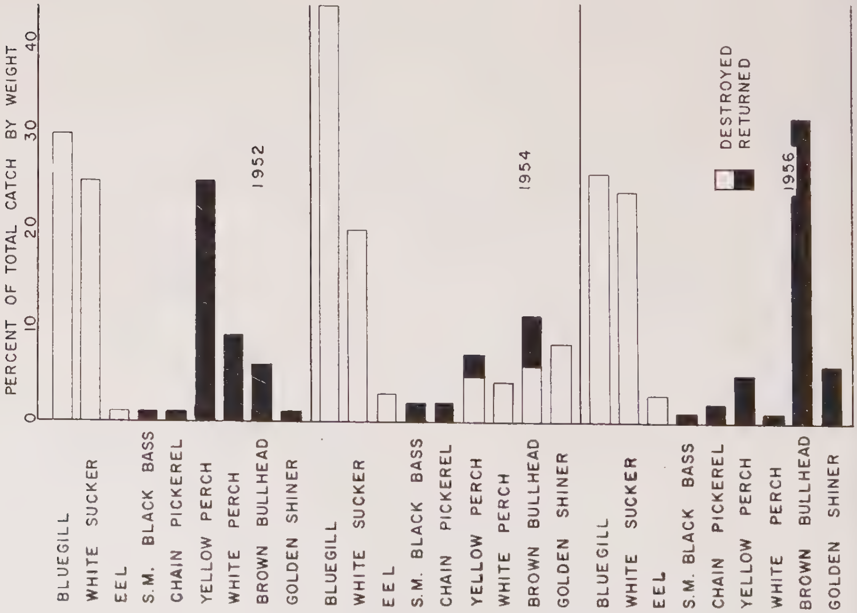

Figure 3.—Catch composition of fyke nets, Billington Sea, Plymouth, Massachusetts in 1952, 1954, and 1956.

Jordan Pond, Shrewsbury

Netting intensity was very heavy on Jordan Pond, Shrewsbury, a small, relatively shallow pond of 20 acres with a maximum depth of 14 feet and an average depth of 5 feet. A total of 5,740 pounds of fish were removed, amounting to 105, 92, and 39 pounds per acre for the years 1953, 1954, and 1955, respectively. Bluegills constituted a little over 40 percent of the total weight of fish taken in 1953 at the start of operations, and in 1954, they again made up about 40 percent (Fig. 4). The 1955 netting produced a catch which was about 65 percent bluegills by weight. Largemouth black bass,

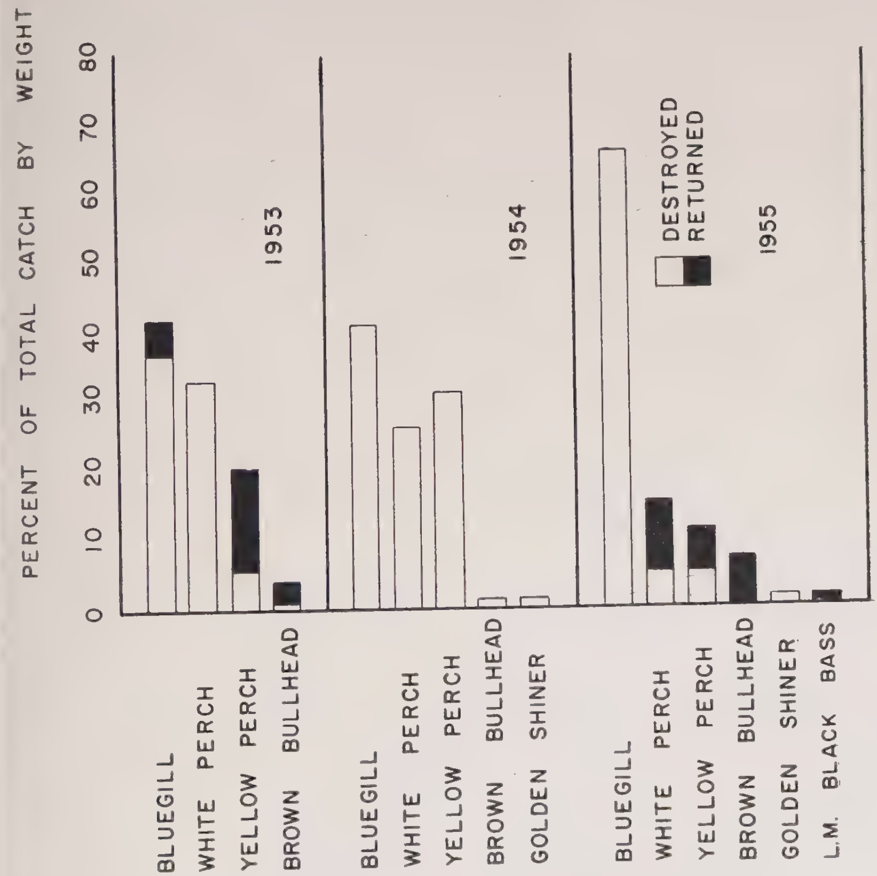

Figure 4.—Catch composition of fyke nets, Jordan Pond, Shrewsbury, Massachusetts, for 1953, 1954, and 1955.

not taken in the 1953 or 1954 netting, constituted one percent of the total in 1955. This slight increase was probably due to a stocking of 7,000 fingerling largemouth black bass in the summer of 1953.

Thinning operations resulted in increased growth for white perch, bluegills, and yellow perch.

DUCK POND, GROTON

Duck Pond, Groton (28 acres) was subjected to moderately heavy netting with 2,020 pounds being removed during two years. In 1953, 44 pounds per acre were removed. About 37 percent of the total weight was of brown bullheads, 21 percent lake chubsuckers, and 20 percent yellow perch. All of the brown bullheads and lake chubsuckers and about half of the yellow perch were destroyed. When netted in 1956, the principal species composition of the net catch was as follows: 56 percent brown bullheads, 16 percent lake chubsuckers, and 9 percent yellow perch. No appreciable increase in gamefish (chain pickerel and largemouth black bass) was apparent.

The average size of brown bullheads had increased from 7.1 inches in 1953 to 10.1 inches in 1956. Bluegills and yellow perch also exhibited increased growth.

DISCUSSION AND CONCLUSIONS

In the lakes considered, only the species removed showed an increase in growth, where changes did occur. In Indian Lake, there was an increased growth rate of white perch, yellow perch, and black crappie, and a slight decrease in the growth rate of chain pickerel and largemouth black bass. This phenomenon was also noted for Jordan Pond, Shrewsbury; Duck Pond, Groton; and other waters not discussed in this paper.

The 1954 year class of white perch from Indian Lake, spawned at the start of the netting operations, was growing at a much faster rate in 1956 than any older year class in the lake. It appears likely that the older fish are not as elastic in their growth rates as younger ones and that fish left in the pond immediately following netting do not benefit as much from the reduction in population density as do their progeny. This results in a delay of from two to three years before these young, faster-growing fish reach desirable size (Fig. 2). How long this faster growth rate will be maintained after the cessation of netting is not known.

In Billington Sea, a total of over five tons of fish were removed from the pond in the years 1952, 1954, and 1956. This amounted to less than 15 pounds per acre in any one year of netting, and, apparently, was insufficient to cause significant increases in the growth rates of the fishes involved. In contrast, a single removal of 44 pounds per acre in 1953 from Duck Pond resulted in greatly increased growth rates and increased average sizes of the principal panfish species.

Even drastic removal of other species failed to increase significantly the proportion of gamefish in the fyke net catches. Percentages of chain pickerel and largemouth black bass in net catches from Indian Lake, Jordan Pond, and Duck Pond showed little or no consistent increase after netting. It is postulated that this was due to increased recruitment of the species being thinned, since the fyke nets take only fish over a certain minimum size. The remaining, rapidly growing, young panfish apparently fill the void rather than the desired gamefish.

It is concluded that fyke net thinning of fish populations in Massachusetts has not accomplished one of its primary objectives; that of creating better gamefish populations. It does appear, however, that it can be an effective tool in increasing, at least temporarily, the average size of panfish if a considerable portion of the standing crop is removed.

ACKNOWLEDGMENTS

Fyke netting operations were carried out by Michael Miskewich, Carleton Hudson, Richard Cronin, and their respective fisheries management crews. Their diligence in collecting data for later analysis is deeply appreciated. For their assistance in compiling and tabulating the data, the author wishes to thank the entire fisheries research staff. Special thanks are due to William A. Tompkins, Chief Aquatic Biologist, and James W. Mullan, Aquatic Biologist, for their assistance and advice in the preparation of the manuscript.

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GROWTH OF THE FISHES IN THE SALT RIVER, MISSOURI

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ABSTRACT

Age-and-growth data are presented for 11 species of fish from three habitats in the Salt River, Missouri; a dredged upstream station, an unmodified lower station and an intermediate middle station. The middle station is 46 stream miles from the upper station and 69 stream miles from the lower station. Compared to growth data from the central United States, carp, *(Cyprinus carpio)*, smallmouth buffalo *(Ictiobus bubalus)*, freshwater drum*(Aplodinotus grunniens)*, green sunfish *(Lepomis cyanellus)* and white sucker *(Catostomus commersoni)* grew moderately fast; gizzard shad *(Dorosoma cepedianum)* at an average rate. River carpsucker *(Carpiodes carpio)* grew very slowly at the upper station and slightly slower than average at the middle and lower stations. Channel catfish *(Ictalurus punctatus)*, flathead catfish *(Pilodictis olivaris)*, northern redhorse *(Moxostoma aureolum)*, and white crappie *(Pomoxis annularis)* grew slowly. All but one of the more abundant species showed a trend toward faster growth downstream; a phenomonen also noted in other Missouri streams. The differences in growth indicate little movement between stations. Freshwater drum of the 1947 year class were very abundant and they and all freshwater drum competing with them grew slowly. Minimum desirable length for angling in this stream is reached by carp (14 inches), buffalo (12 inches) and white crappie (7 inches) in the third year; green sunfish (6 inches) in the fourth year; and catfishes (12 inches) in the fifth and sixth years.

INTRODUCTION

Salt River rises near the Iowa-Missouri border in Schuyler County of northeastern Missouri and flows southeastward 170 miles to the Mississippi near Louisiana, Missouri. The Salt River basin is an almost-level plain of glacial drift of sandy and silty clay in which are imbedded chert fragments. Topography is modified to a certain extent by loess deposits (Branson, 1944). The steepest slopes are along the Salt River and its tributaries where valleys cut through limestone and leave high rock bluffs parallel to the main stream.

Between 1911 and 1928 drainage organizations straightened about 38 miles of the upper reaches of the Salt River with the intention of increasing the rate of run-off and preventing or reducing the effects of minor floods. One result has been that silt and sand deposited just downstream from the straightened channel is rapidly filling the natural channels (U. S. Army Engineers; correspondence).

Flow data of Salt River (Beckman, 1940) for the lower stretches near New London show an average discharge for the 27-year period ending in

1939 of 1,687 second feet with a maximum of 58,700 second feet and a minimum of no flow for 11 days in 1934 and 12 days in 1936. Flow at New London was less than 30 c.f.s. 10 percent of the time and was over 4,000 c.f.s. another 10 percent.

Limited chemical analyses of the water indicate that dissolved oxygen was adequate for fish. The waters were alkaline (pH 7.1 - 7.8). Methyl-orange alkalinity was between 65 and 150 p.p.m. The Salt River is usually quite turbid. Observations made by the U. S. Army Engineers (correspondence) at Monroe City show a minimum load of suspended material of 28 p.p.m. at lower river stages and a maximum of 4053 p.p.m. at high stages. Particle sizes were mostly in the range classified as silt.

Sampling Stations

The upper station is located in the level plains of Adair County near Brashear in an area of loose and friable soil containing sand and fine gravel. The subsoil is clay with lime concretions. The station is in a portion of the straightened channel and there are 11 miles of straightened channel upstream. The channel, which is 40 to 50 feet wide, has been dredged down to clay. Over the clay the coarse material eroded from the soil forms a continuously shifting stream bed. This and the extreme fluctuation of flow, from almost nothing to floods covering all the bottomlands, are the outstanding characteristics of the stream in its upper reaches. The area studied is 2185 feet long and rate of fall 3.8 feet per mile. Normal stream widths are from 5 to 40 feet; the average pool width 28 feet. There are no deep pools but sometimes holes up to 4 or 5 feet deep are scoured out. These fill again with the shifting of the coarse bottom material. In August, 1950, average depth in the 1.39 acre study area was 0.7 feet. The volume of flow was approximately 19 second-feet; about normal summer flow.

The middle station is six miles northeast of Shelbina in Shelby County and downstream 46 miles from the upper station. It is not in the straightened channel area, but all 38 miles of such channel lie upstream. The station consists of two pools of moderate depth connected by a short riffle. There is very little shallow water and the banks are rough and abrupt. Average water depth is about two feet and maximum depth about five feet. The average width is 62 feet. The bottom is of silt and large rocks, which furnish considerable cover. Both banks are forested for a short distance back from the margin, giving way to cultivated fields and pastures as soon as the topography is suitable. This station is 2357 feet long. The surface area in August, 1950, was 3.37 acres. Flow averaged 122 second-feet during that month; more than 6 times that of the upper station. Rate of fall in the vicinity is 2.46 feet per mile. Flooding is aggravated in this portion of the stream by the channel straightening upstream which hastens the water out of those areas too fast for the downstream channels to handle.

The lower station is six miles north of Center in Ralls County; about 69 stream miles below the middle station and about 45 stream miles upstream from its mouth. The area begins in a large pool, and 900 feet downstream splits into two channels. The south channel contains a series of small pools averaging 68 feet in width connected by short riffles and one large pool. The north channel consists of longer riffles and larger pools up to 150 feet wide. Mean depth of the area is two feet and maximum pool depth five feet. Pool bottoms are primarily of silt and riffles are of sand and gravel. Combined channel length of both channels was 6534 feet and surface area was 18.04 acres in August, 1950. During that month the average volume of flow was 252 second feet at the New London gaging station, which is several miles downstream. This is somewhat more than twice the flow at the middle station. The stream margin is wooded except along a high cut bank which borders about half of the north channel. Fields beyond the wooded borders are used for crops, primarily corn. Rate of fall of the stream in this region is about 2.3 feet per mile. Most of the Salt River in this region is made up of a series of long pools in which the water moves slowly.

MATERIALS AND METHODS

Materials for study of fish growth rates were collected at the three stations by fisheries census crews of the Missouri Conservation Commission. The species studied were: freshwater drum *(Aplodinotus grunniens)*, river carpsucker *(Carpiodes carpio)*, carp *(Cyprinus carpio)*, smallmouth buffalo *(Ictiobus bubalus)*, northern redhorse *(Moxostoma aureolum)*, white sucker, *(Catostomus commersoni)*, gizzard shad *(Dorosoma cepedianum)*, green sunfish *(Lepomis cyanellus)*, white crappie *(Pomoxis annularis)*, channel catfish *(Ictalurus punctatus)*, and flathead catfish *(Pilodictis olivaris)*. Scale samples were taken during the fall of 1946, summer and fall of 1947, and each spring, summer and fall of the years 1948 through 1951. Channel catfish and flathead catfish vertebrae were collected in 1950, 1951 and 1952, except for a group of younger fish taken and preserved with small-fish collections of previous years.

Fish were collected with hoop nets of 1- and 2-inch mesh, with ¼- and ½-inch mesh drag seines, and electric seines (Funk, 1949). The variety of devices was intended to eliminate bias resulting from gear selectivity, but length-frequency studies indicate some selectivity toward large fish. This probably was due to the usually turbid waters and a shortage of drag-seining areas particularly at the middle station.

Sex was determined only for fish in spawning condition and sex ratios and growth rates of the separate sexes not calculated. Scale samples were taken from all white crappie and green sunfish over three inches total length. Due to the large numbers of the other species sometimes taken, scales were taken from a sample (25-30) of each collection. A sample of the fish shorter than three inches were preserved and their scales were removed in the laboratory. Scale impressions were made in plastic sheets and aging and measuring done with the aid of a microprojector.

Empirical data for body-scale or body-vertebra relationships were plotted for each species. Usually the relationship was curvilinear, but so slightly that a linear relationship was satisfactory. Regression equations and the length-intercepts of the body axis were determined on this basis. Where empirical data fitted the relationship determined by other studies, that value was used. In some instances empirical data were plotted and the intercept of the body axis was estimated. The value derived for the intercept of the body axis was used for the origin of the nomograph in back-calculations of growth.

A binocular microscope was used to age vertebrae. Measurements of vertebral radii were made with an ocular micrometer while the vertebrae were on a plastic stage designed to afford a plane measuring surface.

An important aspect of these studies is the determination of the age at which fish attain a length acceptable to fishermen. For each species an arbitrary figure was set, often based on former minimum length limits. This arbitrary figure is referred to as "minimum desirable size."

GROWTH RATES OF COMMON SPECIES

FRESHWATER DRUM

Freshwater drum are non-game fish in Missouri, but they are important sport fish in the Salt River where they composed about 2 percent of the creel during 1946-1948, 5 percent in 1949, 20 percent in 1950 and 15 percent in 1951 (Funk, unpublished). A dominant year class accounted for the increase and decline in the catch.

The average calculated total length of freshwater drum from the lower station of the Salt River was 10.5 inches the third year. Those from the middle Salt were 11.3 inches at that age (Table 1). Growth of freshwater drum from the middle station was better during each year of life than for those collected from the lower station (Table 1). For the first five comparable years, the growth increments of fish from the middle station exceeded those from the lower station by an average of 0.2 inches.

Salt River growth was compared with the average growth of freshwater drum from the St. Francis River, Missouri (Purkett)[1], Meramec River, Missouri (Purkett)[2], and the upper Mississippi River (Butler and Smith, 1950). Growth in the middle Salt was very close to that found in the upper Mississippi River and was faster than the average elsewhere. Those at the lower station grew slower than upper Mississippi River freshwater drum, but they grew at equal rates, or faster, than freshwater drum from the other streams.

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[1] Purkett, Charles A., Jr. 1956. A study of the growth rates of the important stream fishes of the St. Francis River watershed. Dingell-Johnson Project Number F-1-R-5. Job Completion Report.

[2] Purkett, Charles A., Jr. 1955. A study of the growth rates of the important stream fishes of the Meramec River watershed. Dingell-Johnson Project Number F-1-R-4. Job Completion Report.

TABLE 1.—*Calculated growth of freshwater drum from the middle and lower Salt River stations.*[1]

Station	Average total length at end of year—inches								
	1	2	3	4	5	6	7	8	9
Average total length									
Middle station	5.1	9.0	11.3	13.2	14.9	16.5	17.9	19.0	20.1
Lower station	4.7	8.3	10.5	12.4	13.8	15.7	16.5	17.7	
Number of fish									
Middle station	130	122	96	51	18	7	7	6	5
Lower station	365	277	174	81	24	4	1	1	

[1] Computations were based on a linear relationship and estimated intercept of the body axis of 0.8 inch.

The 1947 year class was dominant. It made up 28 percent of the total freshwater drum sample from the lower station in 1947, 68 percent in 1948, 69 percent in 1949, 51 percent in 1950, and 29 percent in 1951. At the middle station, the 1947 year class composed 40 percent of the 1948 sample of freshwater drum, 93 percent in 1949, 51 percent in 1950, and 28 percent in 1951. No young-of-the-year freshwater drum were taken from that station in 1947. This year class furnished the great increase in the fisherman's catch which was noted previously. The maximum number were taken by anglers when the 1947 year class was in its fourth year.

Growth rates of the first four age groups were depressed by the slow-growing 1947 year class. Except in 1947, the growth of the large 1947 year class was considerably slower than the average growth of year classes before it (Table 2). This difference at the lower station was 0.4 inch the second year, 0.9 inch the third, and 1.8 inches the fourth. At the middle station the difference was 0.6 inch the second year, 1.3 inch the third and 1.1 inch the fourth.

The large 1947 year class apparently also affected the growth of other freshwater drum present. The average total length of all year classes present during 1948-1951 were from 0.1 to 0.9 inch below the average growth before 1947.

Average lengths of the year classes from the middle station exhibit the same trend but less markedly. Generally, growth was slower when the 1947 year class was competing with other age-groups of freshwater drum. The less pronounced effect at the middle station may be due to the smaller freshwater drum population there.

Length-weight relationships were the same for the two stations. They were determined by the method given by Beckman (1948). The relationship is described by the formula $\text{Log } W = -2.35 + 3.19 \text{ Log } L$, where W equals weight in ounces and L equals the total length in inches. The average weight of a ten-inch drum was 6.9 ounces; at 13 inches the weight had increased to one pound, and at 16.1 inches to two pounds.

TABLE 2.—*Average calculated total length in inches of the 1947 year class of freshwater drum compared with the grand average calculated lengths of preceding year classes.*

Station	Year class	Number	Average total length at end of year—inches			
			1	2	3	4
Lower.........	1947	181	4.7	8.0	10.1	11.0
	1941-1946	121	4.6	8.4	11.0	12.8
Middle........	1947	69	5.1	8.6	10.5	12.6
	1938-1946	52	4.7	9.2	11.8	13.7

Few young-of-the-year freshwater drum were collected from the Salt River during the period 1948-1951. But in October, 1952 a large number of young-of-the-year freshwater drum were caught. That was the sixth year of life of the 1947 year class and it is likely that these young-of-the-year fish were primarily the reproduction of that dominant year class.

RIVER CARPSUCKER

River carpsucker are seldom taken by angling. However, they were abundant and are of interest as a competitor and as a forage species.

Growth of river carpsucker was about equal at all three stations during the first two years of life. The average total lengths for all stations combined were 3.2 inches at the end of the first year and 6.2 inches the second. The average total lengths of fish from the middle and lower stations continued to be about equal through the following years: at the end of the sixth year it was 13.3 inches (Table 3). At the upper station, growth was much slower during the third and following years. Average length at the end of the fifth year of life was 10.5 inches (Table 3): five-year-old fish averaged 1.5 inches shorter than those from the middle station, and 1.8 inches shorter than those from the lower station. Poor habitat, including limited area for food production, apparently impeded growth in the larger fish.

In the Meramec River, Missouri[2] the average length at the end of the first year was 3.1 inches; quite similar to the Salt River growth. But by the end of the fourth year the length of Meramec River river carpsucker exceeded those from the Salt River by one inch. Davis[3] reported an average length of 8.6 inches at the third annulus and 10.7 inches at the fourth for carpsuckers from Perche Creek, Missouri. Salt River river carpsucker from the middle and lower stations were 0.3 inch longer at the fourth annulus. At all stations of the Salt River river carpsucker were available as forage during their first year. After that most of them were too large.

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[3] Davis, James T., 1955. Contribution to the ecology of fishes of Perche Creek, Missouri. Unpublished Master's Thesis. Univ. of Mo. Grad. School.

CARP

Carp were important hook-and-line fish in the Salt River. They ranked first in total weight in the creel. Although considered undesirable in many waters, they make up a high proportion of the creel in turbid streams of Missouri. A considerable amount of fishing is especially for carp.

TABLE 3.—*Calculated growth of river carpsucker from the Salt River stations.*[1]

Station	Average total length at end of year—inches							
	1	2	3	4	5	6	7	8
Average total length								
Upper station	3.4	6.3	7.5	9.5	10.5			
Middle station	3.2	6.4	9.2	11.0	12.0	13.3		
Lower station	3.1	6.1	9.0	11.0	12.3	13.3	15.5	14.6
Number of fish								
Upper station	233	214	97	14	3			
Middle station	190	188	157	105	41	6		
Lower station	325	283	215	161	94	27	5	1

[1] Computations were based on a linear relationship expressed by the equation $L = 0.169 + 0.907S$.

Three hundred forty-three carp scale samples were collected. Only 104 from the middle station and 120 from the lower station could be used. Many samples were discarded because they were regenerated. Few carp were taken at the upper station. Very few carp less than eight inches total length were taken at any station. This probably was because of the fish's habitat preferences in early life.

Recaptured carp tagged with opercular tags were studied to verify the annulus. In three cases, it was verified: in nine, no annulus had formed over periods of one to three years, and these fish had grown very little or not at all. A similar lack of growth for periods up to five years was observed in a number of other tagged carp, from which we had no scales. Owing to the apparent effect of the tag, only the original scales could be used and the later captures were eliminated. Quite a number of scales were badly resorbed. These were finally eliminated as unreliable for calculations. Frey[4] found that carp held under adverse conditions did not form annuli. He also stated that where growth is slow and lateral resorption severe, age determinations could be subject to considerable error.

The average calculated total lengths of carp from the middle station were 4.9 inches the first year, 10.6 inches the second, and 20.2 inches the sixth (Table 4). Carp from the lower station averaged 5.8 inches the first year,

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[4] Frey. David G., 1940. Growth and ecology of the carp. *Cyprinus carpio* Linnaeus in four lakes of the Madison region, Wisconsin. Unpublished Doctor's thesis, Univ. of Wisconsin.

11.6 inches the second, and 20.9 inches the sixth (Table 4). Average total lengths were somewhat higher at the end of each year of life at the lower station than at the middle. The average difference over the first six years of life was 0.85 inch. The desirable size of 14 inches was attained by most fish during their third year, at both stations, but late in this year at the middle station.

TABLE 4.—*Calculated growth of carp from the middle and lower Salt River stations.*[1]

Station	Average total length at end of year—inches							
	1	2	3	4	5	6	7	8
Average total length								
Middle station	4.9	10.6	14.3	17.1	18.1	20.2	21.7	
Lower station	5.8	11.6	15.3	17.5	19.2	20.9	22.9	25.7
Number of fish								
Middle station	102	90	65	44	16	6	2	
Lower station	119	108	95	68	39	15	2	1

[1] Computations were based on a linear relationship expressed by the equation $L = -0.2 + 2.2 S$ (Patriarche, 1953).

Growth of Salt River carp was considered fast for stream fish. They grew faster than those from Lake Wappapello studied by Patriarche (1953). In that impoundment, carp averaged 15.3 inches at the end of four years, about two inches less than fish from the Salt. Carp from the St. Francis River[1], part of which is impounded by Wappapello dam, also grew slower. They averaged about 15.0 inches at the fourth annulus. Those from the Meramec River[2] grew at rates about equal to those from the middle Salt River.

Possible conclusions concerning the abundance of year classes of carp were greatly influenced by the number of unusable scale samples. However, collections from the middle station indicated that the 1948 and 1945 year classes were considerably above average in abundance. The lower station data indicated that 1944, 1945, and 1946 year classes were unusually abundant and that there has been a decline since that time. Carp in the 1948 year class were seldom taken.

The length-weight relationship of carp from the Salt River is described by the logarithmic equation, $\log W = -1.96 + 2.89 L$, where W equals weight in ounces and L equals the total length in inches. The calculated average weight of a 15 inch carp was 27.5 ounces. At 20 inches, the weight increased to 63.0 ounces.

SMALLMOUTH BUFFALO

Seventy-two smallmouth buffalo from the middle and lower stations were studied; none were taken at the upper. Since they were few, they were not considered by station of collection.

Average total lengths of smallmouth buffalo were 5.1 inches at the end of the first year, 9.6 inches the second, 12.8 inches the third, and 20.5 inches the seventh (Table 5). A minimum desirable size of buffalo is about 12 inches. That length was attained late in the third year by smallmouth buffalo in the Salt River.

TABLE 5.—*Calculated growth of smallmouth buffalo from the Salt River.*[1]

	Average total length at end of year—inches							
	1	2	3	4	5	6	7	8
Average total length	5.1	9.6	12.8	15.0	16.9	19.4	20.5	21.8
Number of fish	71	56	50	38	22	6	3	1

[1] Computations were based on a linear relationship and an estimated intercept of the body axis of 1.5 inches.

There have been few studies of this species to use in comparison (Carlander, 1953), but growth was rapid in the Salt River. Eschmeyer, Stroud and Jones (1944) found an average length of 6.4 inches for two-year-old smallmouth buffalo in Chickamauga Reservoir, Tennessee. This is 3.2 inches less than the Salt River fish of like age. In the St. Francis River, Missouri[1] the average length at the third annulus was 10.0 inches; 2.8 inches less than in the Salt River.

NORTHERN REDHORSE

Northern redhorse were not abundant in the Salt River. Only 84 from the middle and lower stations were available for growth study. Nine of these were young-of-the-year. No redhorse were taken at the upper station.

Average total lengths were 3.6 inches the first year, 11.4 inches the fourth, and 14.9 inches the sixth (Table 6). A desirable size of 12 inches was reached in the fifth year of life. Only nine of the fish collected were that old. Eddy and Carlander[5] found that northern redhorse in Minnesota averaged 14.7 inches at the fifth annulus. Kuehn[6] also studying Minnesota fish, found the average length at that age to be 15.0 inches. Both of these studies indicate considerably faster growth than that made by the Salt River population. Growth of northern redhorse was also faster in the St. Francis[1] and Meramec Rivers[2] of Missouri where the average lengths at the third annulus were slightly over 12 inches.

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[5] Eddy, Samuel and Kenneth D. Carlander. 1942. Growth rate studies of Minnesota fish. Minn. Dept. Cons. Fish. Res. Inv. Rep. No. 28, 64 pp. mimeo.

[6] Kuehn, Jerome H., 1949. Statewide average total length in inches each year. Minn. Fish. Res. Lab. Supplement to Inv. Rep. No. 51 (2nd Revision).

TABLE 6.—*Calculated growth of northern redhorse from the middle and lower Salt River.*[1]

	Average total length at end of year—inches					
	1	2	3	4	5	6
Average total length	3.6	6.8	9.7	11.4	13.5	14.9
Number of fish	75	72	49	27	9	5

[1] Computations were based on a linear relationship expressed by the equation $L = 1.45 + 0.97 S$.

WHITE SUCKER

White sucker were common at the upper station but were taken infrequently elsewhere. They were seldom creeled and their primary importance was as forage.

The body-scale relationship of the 59 white sucker studied was found to deviate greatly from a straight line when determined from anterior scale radius, but ventral scale radius measurements gave a straight-line relationship with an intercept near zero. The latter was used for back-calculation of growth.

The average total lengths of white sucker at the ends of the first four years of life were 3.8, 6.8, 9.0, and 11.7 inches. Only three fish taken were in their fifth year and only one was past that age. The white sucker was available as forage during most of the first year of life. Fifteen young-of-the-year fish collected in the fall averaged 4.1 inches total length. The 1949 year class of white sucker was much the most abundant: it composed 60.8 percent of the 1950 collections and 53.8 percent of the 1951 collections.

Growth of white sucker was faster than has been determined in some other studies. Kathrein (1951) found that this species from a section of the Missouri River in Montana averaged 10.1 inches at the end of the fourth year. Spoor (1938) determined that the average length of four-year-old white sucker from Muskellunge Lake, Wisconsin, was 7.5 inches. Kuehn[6] found that the average length of white sucker in Minnesota was 13.1 inches at the fourth annulus. This latter was somewhat better than Salt River growth. However, the growth of the species in the Salt River was good for stream fish.

GIZZARD SHAD

Gizzard shad were never abundant during the study period, but in 1953 drouth reduced the flowing pools to small impoundments and they became very abundant (Purkett, 1957). Their primary value is as forage while small enough to be so utilized. Lagler and Applegate (1942) state that the gizzard shad was both a buffer and a basic food for preferred species in the flood ponds they studied.

Gizzard shad in their third year of life were taken most frequently, making up 43 percent of the total collections. Only two fish had completed four years of life, which indicated a very rapid population turnover. Lagler and Applegate (1942) noted a similar situation in two Indiana ponds. Patriarche (1953), however, found gizzard shad to be long-lived in Lake Wappapello, Missouri.

The average lengths of 62 gizzard shad were 5.1, 9.3, 11.2, 12.5 and 13.6 inches at the ends of the first five years of life. Growth in this stream was slightly faster than was found by Patriarche and Lowry (1953) for gizzard shad from the lower Black River, Missouri. Those fish averaged 5.3 inches at the first annulus and 10.5 inches at the third. Gizzard shad from the middle section of Black River averaged 11.8 inches at the third annulus. Patriarche found the average length of shad to be 4.1 inches at the end of the first year and 8.3 inches the third. This rate of growth was considerably slower than in Salt River shad. The average lengths of gizzard shad from Salt River at the second, third and fourth annuli were very near the average determined for 11 collecting stations on five Missouri watersheds.

GREEN SUNFISH

Green sunfish were abundant in the tributaries and headwaters of the Salt River. They were quite important in the creel from those areas. Growth varied little between stations and averages were combined for the whole river.

The average total lengths of green sunfish at the end of each of the first five years of life were 1.7, 3.2, 4.7, 5.9, and 7.6 inches (Table 7). This was faster growth than that found in Black River, Missouri (Patriarche and Lowry, 1953). The average length at the end of the fourth year of life in Black River was 5.1 inches, which was 0.8 inch less than in the Salt. It was also faster than at the upper and middle stations of the St. Frances River[1], and the two upstream stations of the Meramec River[2], where the average total lengths were 0.9 inch, 0.5 inch, 1.3 inches, and 0.6 inch less, respectively, at the fourth annulus. In the larger waters of the middle and lower White River (Lowry)[7], and the middle Meramec River[2] the averages at the fourth annulus exceeded those of the Salt River by 0.4 inch to 0.6 inch.

TABLE 7.—*Calculated growth of green sunfish from the Salt River.*[1]

	Average total length at end of year—inches				
	1	2	3	4	5
Average total length	1.7	3.2	4.7	5.9	7.6
Number of fish	232	129	49	14	2

[1] Computations were based on a linear relationship and an estimated intercept of the body axis of 0.4 inch.

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[7] Lowry Edward M.. 1954. A study of the growth rates of the important stream fishes of the White River watershed. Dingell-Johnson Project Number F-1-R-3 Job Completion report.

The length of 5.9 inches, which was the average at the fourth annuluus, is a desirable size for fishermen. Many such were taken during the fourth year of life and their growth rate is considered above average.

The 1946 year class of green sunfish was very abundant early in its life. It made up 87 percent of the 1947 collections, 45 percent of those in 1948, 12 percent of those in 1949, and 17 percent in 1950. The growth of all year classes was quite similar.

WHITE CRAPPIE

Crappie were not numerous in the Salt River. They were taken most frequently at the middle station. Of the 98 white crappie used for growth study, 72 were from the middle station. Growth was similar among those from the upper and middle stations and values for the two were combined.

The average calculated total length of those fish from the upper and middle stations at the end of the first four years of life were 2.5, 4.8, 6.9, and 8.3 inches.

The 20 white crappie taken at the lower station grew faster in each year of life. They averaged 3.3 inches the first year, 6.5 inches the second and 7.9 inches the third. The third-year figure was one inch greater than the average for the other stations.

White crappie growth in all of the Salt River was quite slow when compared to growth in lakes. Witt[8] determined that white crappie from five Missouri reservoirs averaged 10.5 inches at the end of the third year. However, growth in those impoundments was better than that determined by several other studies (Carlander, 1953), but all show faster growth than white crappie from the Salt River. The average length at the third annulus of white crappie from the middle St. Francis River station was 9.2 inches[1]. This growth was considerably faster than that of Salt River white crappie, but the St. Francis River population included migrants from an impoundment. Growth of white crappie at the lower St. Francis River station[1] and in the Meramec River[2], was quite similar to that in the lower Salt River, but considerably better than growth of the upper and middle Salt River fish.

The minimum desirable size of crappie is about seven inches. That length was attained in the third year at the lower station and later in the third or early in the fourth year in the middle and upper stations. At that length they weighed about 2.5 ounces. The average length of crappie checked in the creel census was between 6.4 inches and 8.3 inches. The white crappie added little to the Salt River fishery.

CHANNEL CATFISH

Channel catfish were abundant in the Salt River. As a sport fish, they are very much desired. During one year they made up over 40 percent of the Salt River creel and the average for six years was about 20 percent.

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[8] Witt, Arthur B., Jr., 1952. Age and growth of the white crappie, *Pomoxis annularis* Rafinesque, in Missouri. Unpublished Doctor's thesis. Univ. Mo. Grad. School.

The growth rate study was based on 124 usable vertebrae from the lower station, 40 from the middle station and 26 from the upper station. Length frequency distributions at all three stations substantiated the determinations of the winter mark on the vertebrae. There was a regular increase in length with increasing age in all cases. Young-of-the-year fish were used to help determine the amount of growth and the appearance of the vertebrae during the first year. Actual lengths of 17 young-of-the-year collected in the fall agreed well with calculated first year lengths of all age groups. They averaged 2.7 inches in total length; 18 taken late in July averaged 1.5 inches.

The growth rates of channel catfish from the upper and middle stations were quite similar (Table 8). At the end of five years of life, those from the upper station averaged 10.6 inches, those from the middle station 10.7 inches. Average annual increments of growth varied little through those years. The average at the middle station was 2.3 inches; it was slightly less at the upper. This regular rate of growth was not observed in any other Salt River fish. In most others the growth rate is fast the first two years and after that decreases considerably.

Growth of channel catfish at the lower station was somewhat better than at the upstream stations (Table 8). The average of the annual increments of the first five years was 2.6 inches. The average total length at the end of the fifth year was 11.7 inches; one inch greater than at the middle station. Most fish at the lower station attained a desirable size of 12 inches in the fifth or early in the sixth year of life. Most of those from the upper and middle stations did not attain that size until late in the sixth year.

Salt River catfish growth was slow. Appelget and Smith (1951) determined that channel catfish from the upper Mississippi River at Lansing, Iowa,

TABLE 8.—*Calculated growth of channel catfish from the three stations of the Salt River.*[1]

Station	Average total length at end of year—inches								
	1	2	3	4	5	6	7	8	9
Average total length									
Upper station	2.7	4.7	6.8	8.6	10.6	13.6	15.9	17.7	
Middle station	2.4	4.4	6.7	8.9	10.7	12.5	14.0	15.8	19.9
Lower station	2.6	5.3	8.1	10.2	11.7	13.4	15.7		
Average annual increment									
Upper station	2.7	2.0	2.0	2.2	2.4	2.8	2.2	1.8	
Middle station	2.4	2.0	2.3	2.4	2.4	2.2	2.2	2.5	3.0
Lower station	2.6	2.6	2.9	2.6	2.4	2.0	1.8		
Number of fish									
Upper station	26	23	21	12	7	3	2	2	
Middle station	40	39	34	28	13	9	6	4	2
Lower station	124	84	48	30	15	6	2		

[1] Computations were based on a linear relationship expressed by the equation $L = 0.84 + 0.103 V$.

averaged 14.16 inches at the end of the fifth year of life. They state that growth was slow; yet their fish averaged 2.5 inches longer than lower Salt River catfish of similar age. Marzolf[9], studying Lake of the Ozarks (Missouri) channel catfish, found even slower growth. His channel catfish averaged only 9.5 inches at the fifth annulus and 12.8 inches at the eighth. He also stated that this population exhibited very slow growth.

The length-weight relationship of channel catfish from the Salt River is expressed by the equation, $\text{Log } W = -2.65 + 3.30 \log L$. The calculated weight of a 12-inch fish was eight ounces. One pound was the calculated weight at 14.7 inches.

FLATHEAD CATFISH

Flathead catfish furnished a rather small percentage of the fish caught by sport fishermen in the Salt River, but they provided a much large percentage of the total weight. Fifty-three vertebrae from flathead catfish from the middle and lower stations were usable for age and growth studies. They were treated in the same manner as the channel catfish.

Flathead catfish grew about three inches per year during their first four years of life. At the end of the fourth year the average total length was 11.8 inches (Table 9). The average length at the end of the seventh year was 17.8 inches. A desirable size of 12 inches had been attained by most fish early in the fifth year. Approximately half of those in their fourth year were over that length.

TABLE 9.—*Calculated growth of flathead catfish from the middle and lower stations of the Salt River.*[1]

	Average total length at end of year—inches								
	1	2	3	4	5	6	7	8	9
Average total length . . .	3.0	6.1	9.1	11.8	13.7	16.6	17.8	19.8	23.6
Number of fish	52	48	43	31	19	8	6	2	1

[1] Computations were based on a linear relationship and an estimated intercept of the body axis of 0.85 inch.

Barnickol and Starrett (1951) determined that four-year-old flathead catfish from the Missouri-Illinois section of the Mississippi River averaged approximately 17 inches total length. Those from the Iowa-Illinois section were about 15 inches. Catfish from both Mississippi River sections showed greater average lengths at all ages than did those from the Salt River. Jenkins (1952) found that the length of flathead catfish from Grand Lake, Oklahoma, at the end of the fourth year of life varied from an average of 10.2 inches near steep, chert-covered shore lines to 19.3 inches in shallow silt-bottomed inlets.

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FACTORS INFLUENCING GROWTH RATES

The very abundant 1947 year class of freshwater drum depressed the growth rates of all year classes of that species while it was present. However, they brought about a greater harvest by anglers. There was a ten-fold increase in fishing success for freshwater drum when the 1947 year class reached a desirable size. In a similar manner, the smallmouth bass in several Missouri streams produced a very large 1952 year class (Missouri Conservation Commission, typewritten reports) which, though they also grew slowly, made a great number of fish available for the fishermen. In these instances, year class abundance was very important to the stream fishery and a strong year class sustained the fishery for several years.

The growth of four of the six species most important in the Salt River creel (carp, freshwater drum, smallmouth buffalo, green sunfish) was above average for Missouri streams. The two other important species, channel catfish and flathead catfish, grew slowly. River carpsucker were very abundant and also grew slowly, suggesting over-population. The competition with the river carpsucker may have contributed to slow growth of channel catfish and flathead catfish. However, small channel catfish also were very abundant and intra-specific competition may have been a limiting factor. Their slow growth made for excessive mortality before they were available for the creel. Northern redhorse and white crappie were not well suited for the habitat; that is reflected by slow growth and small populations of both.

The trend was for faster growth downstream. Among those species present in considerable numbers at both stations, growth was better at the middle station than at the upper. It was better at the lower than at the middle in four of seven species common to both stations. Two species grew at the same rates and one, the drum, grew faster at the middle station. Faster growth downstream also was found in the fish populations studied at four stations on the Meramec River, Missouri[2] and Lowry[10] determined that smallmouth bass from six Missouri Ozarks streams had the same trend. Slow growth in the upper section of the river is due partially to the straightened channel which furnishes the poorest fish habitat in the river. However, the studies mentioned above and other studies of Missouri streams (Missouri Conservation Commission, typewritten reports) indicate that the normal growth pattern of stream fish is for faster growth downstream.

ACKOWLEDGMENTS

John Funk began the stream fishery studies of which this is a phase. He has provided suggestions throughout the study and during the preparation of the manuscript. Thanks are due also to the several members of the Missouri Conservation Commission staff whose efforts helped implement the study in many ways. The project was financed by Federal Aid to Fish Restoration funds under Dingell-Johnson Project Number Missouri F-1-R.

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REARING METHODS AND THE RETURN OF FALL-MIGRATING CHINOOK SALMON

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Abstract

Return of planted fin-clipped juveniles of fall-migrating chinook salmon *(Oncorhyncus tshawytscha)* as 3- and 4-year-old spawners is considered in relation to four different rearing methods. Four groups of salmon, of about 30,000 each, were first reared for 78 days in fresh-water and all eventually planted in estuarial waters (salinity about 22 parts per 1,000) at the mouth of the Samish River. Highest return of spawners to the Samish River (0.75 percent) was from juveniles subjected to a 5-day conversion to 75 percent sea water after fresh-water rearing and prior to stocking. Second highest return (0.47 percent) was from fish planted directly after fresh-water rearing. Third highest return (0.26 percent) was from fish subjected to an 8-day conversion to 100 percent sea water followed by 25 days of rearing in sea water. Lowest return (0.19 percent) was from fish handled as the preceding but having a 60-day rearing period in salt water. Sizes of fish in a planting were respectively 150, 150, 49, and 25 to the pound. Rearing in and conversion to salt water was carried out about 30 miles by water from the Samish Hatchery where the fresh-water rearing was done. Migrational timing on return to the Samish River was similar for marked fish and unmarked fish in the run

Introduction

A prime objective in artificial rearing of salmon is increased survival of planted fish as indicated by return of planted fish as adult spawners. To this end many approaches have been used, including improvement of diets, disease control, size control, and selective breeding. Different approaches have been stressed by different fisheries agencies. However, such approaches have been found mostly applicable to those kinds of salmon that have a natural feeding period, as juveniles, in fresh water — especially to chinook (king) salmon *(Oncorhyncus tshawytscha)* and sockeye (red) salmon *(O. nerka)*. For these two species artificial rearing in fresh water has proven effective in increasing survival (Wash. Dept. Fish., 1947).

However, rearing of chum salmon *(O. keta)* and pink salmon *(O. gorbuscha)* is more difficult because the young of these salmon feed little or not at all in fresh water. For these no fresh-water rearing procedure has been developed for which increased return from planted fish has been demonstrated. To meet this difficulty, the Washington Department

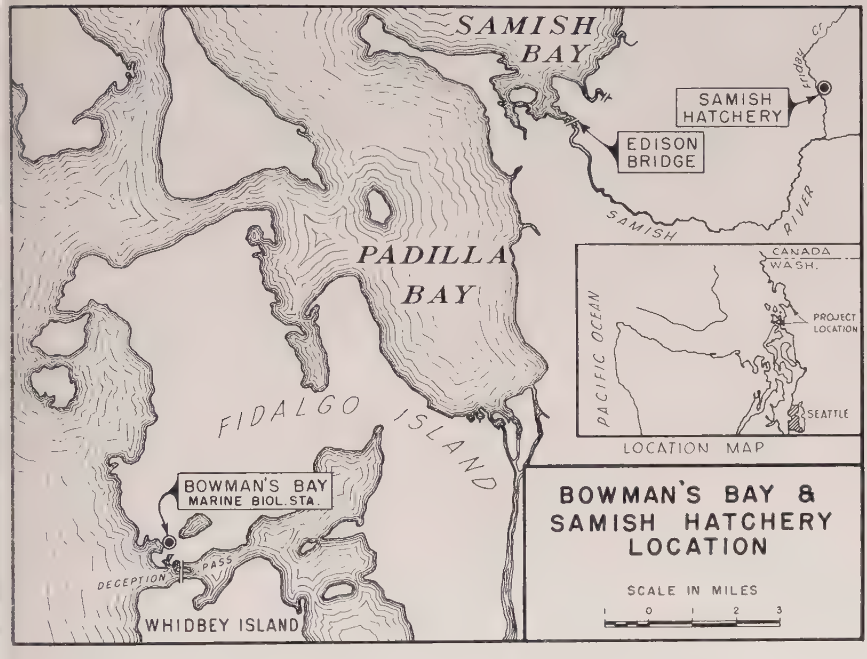
SAMISH BAY
SAMISH HATCHERY
Friday Cr.
EDISON BRIDGE
SAMISH RIVER
PADILLA BAY
FIDALGO ISLAND
BOWMAN'S BAY MARINE BIOL. STA.
DECEPTION PASS
WHIDBEY ISLAND
CANADA
WASH.
PACIFIC OCEAN
PROJECT LOCATION
SEATTLE
LOCATION MAP
BOWMAN'S BAY & SAMISH HATCHERY LOCATION
SCALE IN MILES
1 0 1 2 3

FIGURE 1.—Location of chinook salmon rearing stations and fish release point on Puget Sound.

of Fisheries has, for the past 15 years, carried on an extensive experimental program of rearing pink and chum salmon in sea water and it has been found that extended rearing and feeding of these species in salt water can substantially increase returns from planted fish (Wash. Dept. Fish., 1950).

During this same period, some work was also done on rearing of fall-migrating chinook salmon — commonly known as "fall chinook" — in sea water after rearing in fresh water for a normal feeding period of about three months. Usually, the additional rearing period in salt water was 30 to 100 days. Returns from marked fish so reared indicated no benefit from the rather extensive additional rearing period in salt-water. It was decided, therefore, to vary the length of exposure to salt water before planting from a 5-day conversion period to an 8-day conversion period followed by 60 days of rearing in sea water and to check returns of marked adult fish so handled against fish planted directly after fresh-water rearing. The present paper presents the results of this experiment.

REARING AND STOCKING OF EXPERIMENTAL FISH

In 1953 a lot of about 125,000 fall chinook salmon were reared in fresh water for 78 days at the Samish State Salmon Hatchery. This hatchery is located on a branch of the Samish River in western Washington (Fig. 1). During the 78-day rearing period, the young fish increased in average weight from 995 to 150 to the pound. At the end of this rearing period the fish were separated into four groups, (Table 1), and fish of each group marked with a distinctive fin clip.

TABLE 1.—*Rearing procedures, fin marks used, and survival of fall chinook salmon to 3- and 4-year-old spawners.*

	Mark	Rearing procedure			Planting weight	Percentage survival rate
Group	Fin clip	Period in fresh water	Period of conversion to salt water[1]	Period in 100 percent salt water	Fish per pound	Planting to adult spawners
No. 1	Dorsal	78 days	None	None	150	0.47
No. 2	Left ventral	78 days	5 days (75)	None	150	0.75
No. 3	Right ventral	78 days	8 days (100)	25 days	49	0.26
No. 4	Adipose	78 days	8 days (100)	60 days	25	0.19

[1] Figures in parenthesis are percentage sea water.

Fish of Group 1 (marked with a dorsal fin clip) were liberated immediately after fresh-water rearing and marking into estuarial waters at the mouth of the Samish River near Edison Bridge (Fig. 1). Salinity here at high tide is about 22 parts per thousand. The remaining fish (Groups 2, 3, and 4) were transported by tank truck to the Marine Biological Station on Bowman's Bay which is about 30 miles by water from the Samish River. Here, both fresh and salt water were available for controlled conversion from fresh to salt water and facilities were at hand for rearing in salt water.

At Bowman's Bay fish of Group 2 (marked with left-ventral fin clip) were subjected to a 5-day conversion period from fresh water to water with a salinity of 75 percent sea water (the approximate salinity of the Samish estuary). Salinity by days was 25, 50, 60, 70, and 75 percent of that of sea water. Group-2 fish were then planted in the same manner and place as those of Group 1 and were of the same weight as fish of Group 1; that is, 150 to the pound. Fish of Group 3 (marked with a right-ventral fin clip) were subjected to an 8-day conversion to 100 percent sea water; percentages by days being 25, 50, 75, 85, 90, 95, and 100. They were

TABLE 2.—*Returns of adult fall chinook salmon from plants of juveniles subjected to different rearing methods.*

Group	Fish planted	Returns to hatchery								Total returns[1]			
		1955 3-year-old fish				1956 4-year-old fish				To hatchery		To river below hatchery	Grand total
		Male	Female	Avg. wgt. lbs.	Total 3's	Male	Female	Avg. wgt. lbs.	Total 4's	Male	Female	Stream survey 10/7/56	
No. 1	30,386	67	0	10.2	67	34	30	15.6	64	101	30	12	143
No. 2	29,940	100	1	11.3	101	45	61	15.9	106	145	62	11	218
No. 3	30,540	21	0	9.2	21	29	26	14.2	55	50	26	3	79
No. 4	31,156	5	0	10.6	5	26	18	16.5	44	31	18	7	56
Total	122,022	193	1		194	134	135		269	327	136	33	496

[1] Stream survey numbers were obtained from fish that had spawned and died below hatchery racks, sexes were not segregated. No stream survey conducted in 1955 on 3-year-olds.

then reared in 100 percent sea water for 25 days to a weight of 49 to the pound before planting in the same manner and place as were fish of the preceding groups. Fish of Group 4 were handled similarly to those of Group 3 except that they were reared in 100 percent sea water for 60 days to a weight of 25 per pound before planting.

During the period of conversion to salt water and rearing in salt water, all fish remained in excellent condition and had mortality rates never in excess of one percent a week and usually less than 0.5 percent a week.

RETURN OF MARKED FISH

The marked chinooks which were planted in 1953 returned to the Samish River as 3- and 4-year-old spawners in the falls of 1955 and 1956. Details on numbers of marked fish recorded at the hatchery and from the Samish River below it are given in Table 2. It will be noted that from the 122,022 fish planted there were 496 recorded returns in the two years. Males made up 193 of the 194 returns of 3-year-old fish in 1955 and returns of 4-year-old fish in 1956 were about evenly divided between males and females (134 to 135).

Returns, percentage-wise, of marked fish were highest (0.75 percent) for those fish that had been subjected to the 5-day conversion period to 75-percent sea water; were next highest (0.47 percent) for fish planted immediately after fresh-water rearing; third highest (0.26 percent) for fish subjected to an 8-day conversion to 100 percent sea-water followed by 25 days of rearing in sea water and were lowest (0.19 percent) for fish with 8-day conversion to sea water followed by 60 day salt-water rearing.

These results are contrary to findings of some other salmon rearing-and-return experiments in which there has been strong evidence that the larger the fish at time of liberation, the better the survival. Fish of Group 4 which were liberated at a weight of 25 to the pound had the lowest return and those of the smallest average size (150 to the pound) showed the highest return (in Group 2) and next to highest return (in Group 1). Fish of Group 3, which were intermediate in size (47 to the pound) ranked in return between Groups 4 and 1. Results from the Group planting (5-day conversion to 75 percent sea water) were superior to those of the other groups in all respects except average weight. Average weight 4-year-old fish was somewhat greater for fish of Group 4 (16.5 as compared to 15.9 pounds). However, this difference in average weight reflects the greater proportion of females, which are smaller than males in chinooks, in the returns from Group 2.

PATTERN OF RETURN MIGRATION

The data were examined to determine whether or not the migrational timing of the return of marked fish differed appreciably from that of

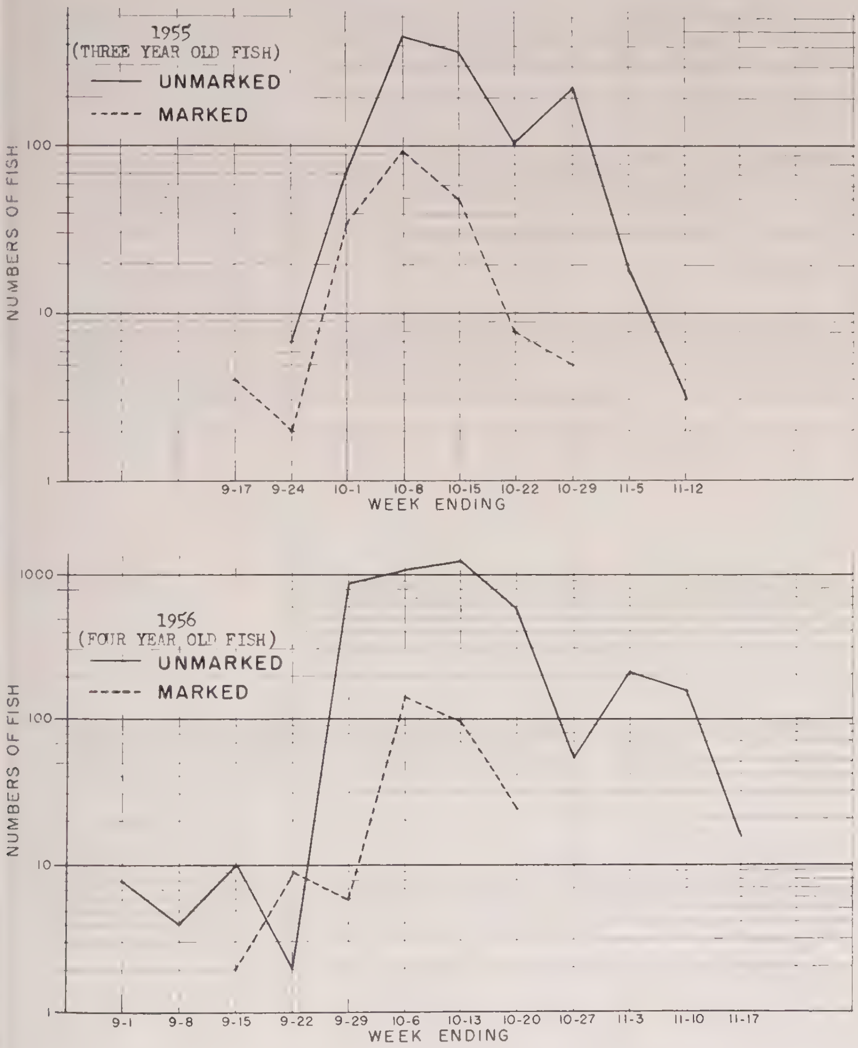

FIGURE 2.—Pattern of returns to Samish Hatchery, Washington, of adult fall chinook from planting of experimentally reared juveniles (marked fish) and naturally reared fish (unmarked), during seasons of 1955 and 1956.

naturally reared and unmarked fish. No important differences were noted between the return patterns of the fish from the separate marked groups and all marked fish are combined in Figure 2 for comparison of return patterns of marked and unmarked fish. It will be noted that marked and unmarked fish both show the same general migrational return pattern with peaks early in October in both years.

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AGE AND GROWTH OF THE AMERICAN SHAD, FROM THREE ATLANTIC COAST RIVERS

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ABSTRACT

Study of age and rate of growth of the American Shad *(Alosa sapidissima)* in three southeastern coastal rivers (St. Johns River, Florida, Neuse River, North Carolina and Susquehanna River, Maryland) shows similar growth rate in these three streams and a body-scale relationship that can be described by the parabolic equation, $y = 22.58x^2 + 34.96x + 0.41$. When allowance is made for differences in aging methods, it appears that growth was similar to that reported in the literature for shad from two Canadian populations. Little difference was found in length of males and females of the same age but males matured earlier and were generally more abundant in commercial catches. The annulus appears to be a true year-mark on scales of shad spawning for the first time and results from aging of these fish from scales are not in conflict with known facts about the shad. Spawning marks are considered to be year-marks for "repeater" shad, that is, shad that have spawned more than once, but this has not been validated.

INTRODUCTION

Production of shad *(Alosa sapidissima)* along the Atlantic coast has declined sharply since 1896. At that time, the catch was 50 million pounds as compared to 17 million pounds in 1946 and 8 million pounds in 1950. In 1950, the U. S. Fish and Wildlife Service began an Atlantic-coast shad investigation initiated by the Atlantic States Marine Fisheries Commission. The purposes of this investigation are to determine the causes of the decline of shad since the turn of the century and to suggest measures for the restoration of the shad populations to their former levels of abundance. The ultimate objective is the suggestion of management measures for maximum sustained yields from each population.

This paper is concerned with age and growth of shad from the St. Johns River, Florida; the Neuse River, North Carolina; and the Susquehanna River, Maryland and with the validation of the annulus as a true year mark for shad.

Leim (1924) studied age and rate of growth of shad as part of life history studies of this species in Canadian waters. He determined age from counts of annuli on scales. Borodin (1925) counted the transverse grooves on the scales and divided by two to determine age in years. Barney (1925) confirmed Borodin's method by the study of otoliths. Greely (1937) questioned Borodin's method. His annuli counts agreed closely with those of Leim. Cating (1953) used annuli to determine age and separated true from false annuli, to the fourth annulus, by a method of transverse groove counts. By using easily-read scales, he found that the number of transverse grooves within each annulus was quite constant in all fish examined.

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American shad are anadromous and spawn during late winter (February-March) in the St. Johns River and in the spring (April-May) in the Neuse and Susquehanna Rivers. The young-of-the-year fish remain in fresh or brackish water until fall (October-November) when they migrate to the sea. Here they stay from two to five years before returning to fresh water to spawn for the first time.

Prior to the initial spawning run, true annuli are formed each year on shad scales. During the initial and subsequent runs, spawning marks are formed. These marks probably are true year marks (Cating, 1953) but differ in form from the pre-spawning annuli. In the present paper annuli are denoted by Roman numerals, and spawning marks by Arabic numerals. Since all adult shad were caught during the spawning season, the edge of the scale was designated as the location of a spawning mark. Age class of a shad is denoted by two numerals (an age-class III-1 shad has 3 true annuli and one spawning mark and is approximately 4 years of age).

A shad that has spawned more than once is termed a "repeater." An examination of scales indicates there are few "repeaters" in the rivers investigated south of Chesapeake Bay. No repeaters were taken from the St. Johns River, Florida and repeaters made up less than 3 percent of the sample from the Neuse River, North Carolina, but were 37 percent of the sample from the Susquehannna River, Maryland. Since growth could not be calculated from scales of repeaters, because there was considerable resorption of the scale edge during the spawning run, only scales from "non-repeater" fish were used in this study and conclusions concerning growth apply only to such fish.

METHODS OF INVESTIGATION

COLLECTION OF MATERIAL

Scales and data from 2038 adult and 164 immature shad collected during investigations on the St. Johns, Neuse, and Susquehanna Rivers, were available at the Beaufort laboratory. The St. Johns River sample was taken by gill nets and haul seines. The Neuse and Susquehanna River samples were taken by gill nets and pound nets. Immature shad were caught by a surface trawl similar to that described by Massmann, Ladd, and McCutcheon (1952). The commercial gill nets used had mesh of 5- to 6-inch stretch measure and therefore selected the larger fish although some small fish were also caught. Pound nets and haul seines, with smaller mesh, ranging from

2- to 3-inches stretch measure, were less selective. Since part of the collection from each of the rivers was taken by haul seines and pound nets, it is assumed that the composite samples for each river contain fish from all age classes present.

Fork-length measurement to the nearest tenth of an inch, weight to the nearest tenth of a pound, and sex were determined for each fish. To facilitate accurate measurement, scales were taken from the left side of the fish in an area below the insertion of the dorsal fin and at about one half the body depth. In this area on shad most scales are symmetrical.

PREPARATION AND EXAMINATION OF SCALES

Scales of shad are not imbedded tightly and are easily lost. Many of those in the samples were of the regenerate type. Such scales and those showing resorption at their edges were discarded. Plastic impressions of 2 scales used for the growth study were read twice; the first reading to determine age and the second to check age and mark the positions of the focus and annuli on strips of paper. A nomograph (Carlander and Smith, 1944) was used to determine the fork length of the fish at the time of annulus formation.

BODY-SCALE RELATIONSHIP

The body-scale relationship was determined from a sample of 615 adult and 164 immature shad taken from the three rivers. An examination of the variation in the relationship between body length and scale radius length by sex for samples from each river revealed only small differences. Inspection of the original data, after plotting length of scale radius (y) against fork length (x), (Figure 1), showed that the body-scale relationship was such that it could be described approximately by the parabolic equation $y = ax^2 + bx + c$; which when fitted to the data on body length of scale radius, has the following value: $y = 22.58x^2 + 34.96x + 0.41$.

AGE AND GROWTH OF SHAD

AGE-CLASS DISTRIBUTION

Age-class distribution of 1691 shad taken in commercial catches from the St. Johns, Neuse, and Susquehanna Rivers is shown in Table 1. Differences in age-class distribution by sex in each river indicates general earlier maturity of the males. Although a few 2-year-old males have been captured in streams, presumably on their first spawning run, most of the male first-spawners were 3 years old in the St. Johns River and 4 years old in the Neuse and Susquehanna Rivers. A few females spawned first at 3 years of age, but the majority of them spawned first at 4 and 5 years of age. Shad between 6 months and 2 years of age were not available for this study because shad of these ages were at sea and not present in the rivers.

TABLE 1.—*Percentage of non-repeater shad by sex and age class from the St. Johns, Neuse, and Susquehanna Rivers.*

	St. Johns		Neuse		Susquehanna	
Age class	Male	Female	Male	Female	Male	Female
I-1					9	
II-1	61	5	16	1	5	
III-1	33	29	58	25	60	44
IV-1	6	56	26	44	21	46
V-1		10		28	5	10
VI-1				2		
Total number	193	487	400	289	92	230

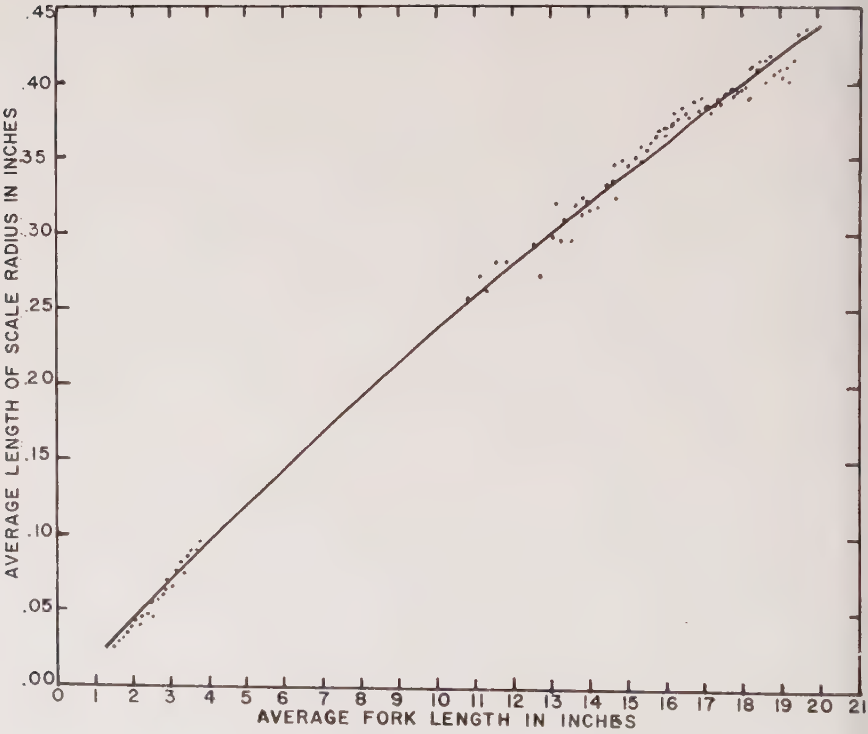

FIGURE 1.—The body-scale relationship of American shad from three southeastern rivers using curvilinear regression line.

GROWTH OF SHAD

Two shad of each sex were selected from each river by 0.1 inch size class for growth determination. Of the 1691 shad in the samples 431 were selected by this method. Female shad had a slightly faster rate of growth than males, but the difference in length between males and females of the same age class was not large. Figure 2 shows graphically differences in average growth rate and growth increment for 164 male and female shad from the Neuse River. At 4 years of age (age class III-1) females from the St. Johns River were calculated to be 0.6 of an inch longer than the males. Females from the Neuse River were 0.3 inch longer, and from the Susquehanna River 1.1 inches longer than the males (Table 2).

The relationship between fork length and total length of shad was determined so that the growth rates calculated in this study could be compared with those of other studies. Total and fork-length measurements were available[2] from 98 shad ranging in length from 15 to 22 inches. The average conversion factor for total to fork length was 0.894. This conversion factor may be subject to a small error for shad less than 15.0 inches in length.

Leim (1924, Figure 37) illustrates a scale from one of four 2-year-old shad from 6.3 to 7.8 inches fork length.[3] By using the nomograph previously mentioned, the first annulus (fresh-water mark) was calculated to have been formed when the fish was between 3.2 and 3.8 inches fork length; the second annulus between 5.4 and 6.5 inches fork length. Hammer[4] shows that the first ring (fresh-water mark) is formed when the shad leaves fresh water in the autumn of its first year. Therefore, the fresh-water mark is not a true annulus. He used 362 adult shad from the Susquehanna River to calculate the length of juveniles at the formation of the fresh-water ring. The mean of these calculated lengths was 3.6 inches.[5] This compares closely with the calculated length at the first annulus of Leim's Figure 37 (3.2 to 3.8 inches). By comparing Cating's Figure 3 (1953) with Leim's Figure 37 it can be seen that the scale in Figure 3 is similar to the area enclosed by the first ring in Figure 37. Figure 3 is of a scale from a 4- or 5-months old shad captured in fresh water. Smith (1899) says, "When 2-months-old, shad are about 2 inches long; having attained this size, they add about an inch to their length in from 2½ to 3½ months, so that when they leave the fresh water in the fall they are from 3½ to 4 inches long." The foregoing observations indicate that Leim was calling the fresh-water mark the first

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[2] Unpublished data, U. S. Fishery Laboratory, Beaufort, N. C.

[3] The total length in centimeters of Leim (1924) was changed to fork length in inches by converting total length to inches and multiplying by the conversion factor 0.894.

[4] Hammer, Ralph Curtis, 1942. The homing instinct of the Chesapeake shad, *Alosa sapidissima* Wilson, as revealed by a study of their scales. Thesis, University of Maryland (typewritten).

[5] Total length in half-centimeters of Hammer (1942) was changed to fork length in inches.

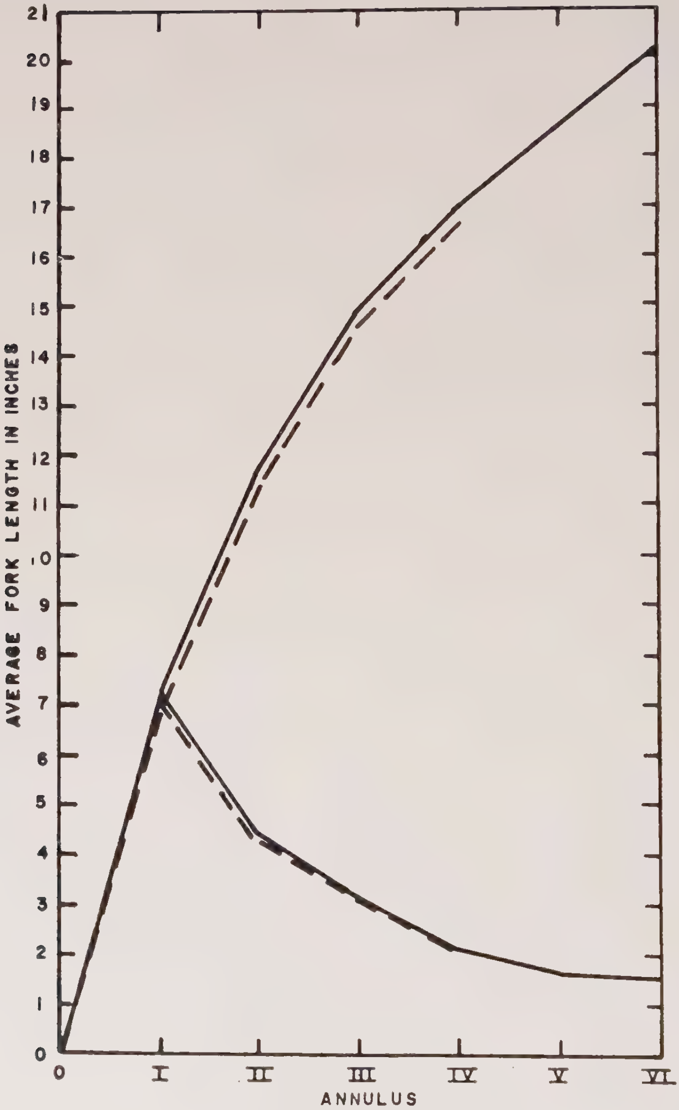

FIGURE 2.—Average calculated fork length at each annulus and average annual increment of male (broken line) and female shad (solid line) from Neuse River.

annulus, thus causing a difference of one year between his age determinations and those in this study.

Material from the St. Johns, Neuse, and Susquehanna Rivers considered in this report was compared to Leim's (1924) growth study of 5-year-old shad from Scotsman Bay, Nova Scotia, in 1920 (Table 2). The calculated lengths in his study agreed quite closely with those of the samples from the three United States rivers after correction for the one year difference in age determination.

VALIDITY OF THE ANNULUS OF SHAD SCALES AS A YEAR MARK

Heretofore, no attempt has been made to validate the annulus on shad scales as the true year mark. The following three criteria of validation, similar to those suggested by Hile (1941), were applied.

1. *Modes in the length-frequency distribution of the sample should coincide with the mean calculated lengths of age groups based on scale reading.* When this method is applicable, it is usually adequate only for fish which are four years of age or younger (Rounsefell and Everhart, 1953). Two thousand thirty-eight specimens were used to find the length-frequency distributions of shad in the three rivers (Table 3). The means of the calculated fork lengths at annulus III and IV of males from the St. Johns and Neuse Rivers (Table 4) agree closely with the modes in the length-frequency

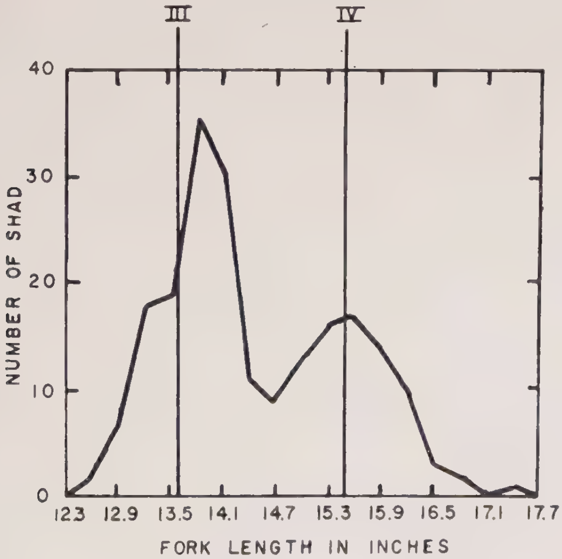

FIGURE 3.—Length-frequency distribution of 208 St. Johns River shad (males) compared with mean calculated lengths at annuli III and IV.

TABLE 2.—*Average calculated fork lengths in inches at each annulus for shad from samples taken from several populations along the Atlantic coast.*

River	I		II		III		IV		V		VI	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
St. Johns	6.9	7.1	10.9	11.2	13.6	13.9	15.5	16.1	—	17.6	—	—
Neuse	7.0	7.2	11.3	11.6	14.5	14.8	16.6	16.9	—	18.6	—	20.2
Susquehanna	6.5	6.9	10.5	11.2	13.0	14.2	14.8	15.9	15.9	17.5	—	—
Scotsman Bay 1920[1]	7.1	7.6	10.3	11.2	12.9	13.9	15.3	16.4	—		—	—

[1] After Leim (1924) with adjustment as described in text.

distributions (Figures 3 and 4). There were too few age-class II-1 female shad in the samples from the three rivers and in the male sample from the Susquehanna River to make modes in the length-frequency distributions (Table 3, footnotes). Also, there were no modes in the length-frequency distributions for age-class III-1 and IV-1 females from all three rivers and males from the Susquehanna River probably because of the overlap in lengths of shad in these two age classes. Therefore, this test could be used only for male shad from the St. Johns and Neuse Rivers.

TABLE 3.—*Length-frequency distribution of shad from the St. Johns, Neuse, and Susquehanna Rivers.*

Fork-length (inches)	St. Johns		Neuse		Susquehanna	
	Males	Females	Males	Females	Males	Females
10.4-10.6					1	
10.7-10.9					2	
11.0-11.2					1	
11.3-11.5					4	
11.6-11.8					1	
11.9-12.1						
12.2-12.4						
12.5-12.7	2				2[1]	
12.8-13.0	7				1	
13.1-13.3	18	1	3			
13.4-13.6	19	1	7			
13.7-13.9	36[1]	2	7			
14.0-14.2	30	3	13[1]			
14.3-14.5	11	7[1]	20		3	
14.6-14.8	9	10	15		5	
14.9-15.1	13	15	16		4	
15.2-15.4	16	20	8		7[2]	
15.5-15.7	17[2]	18	17	1	20	
15.8-16.0	14	31[2]	47	1[1]	42	
16.1-16.3	10	37	60[2]	1	31	4
16.4-16.6	3[3]	58	89	2	31[3]	5
16.7-16.9	2	82	70	5	24	12[2]
17.0-17.2		74	45	10[2]	21	28
17.3-17.5	1	67[3]	20	22	25	47
17.6-17.8		41	11	32	7	35
17.9-18.1		27	6[3]	51	3	56[3]
18.2-18.4		11	3	36[3]		32
18.5-18.7		7		45		35
18.8-19.0		7		39		18
19.1-19.3		1		32		6
19.4-19.6			1	25		9
19.7-19.9				7		2
20.0-20.2				5		3
20.3-20.5				4		1
20.6-20.8				3		1
20.9-21.1				1		
21.2-21.4						1
Totals	208	520	458	322	235	295

[1] Mean fork length at age class II-1.

[2] Mean fork length at age class III-1.

[3] Mean fork length at age class IV-1.

2. *There should be a regular increase in fish length with each succeeding annulus.* Such an increase is noted in successive age groups for both sexes in the samples from each river (Table 4).

3. *There should be a close agreement between average calculated length of a fish at any annulus and the average actual length of the fish of the*

TABLE 4.—*Average fork length at capture and average calculated fork length at each annulus of shad from St. Johns, Neuse and Susequehanna Rivers—expressed as inches.*

River and item	Number specimens	Age class	Sex	Length at capture	Annulus					
					1	2	3	4	5	6
St. Johns	36	II-1	M	13.7	6.9	11.0				
	14	II-1	F	14.4	6.9	11.3				
	31	III-1	M	15.5	6.9	10.8	13.6			
	33	III-1	F	15.8	7.1	11.0	13.8			
	7	IV-1	M	16.5	6.8	10.7	13.4	15.5		
	24	IV-1	F	17.3	7.1	11.2	14.1	16.1		
	18	V-1	F	18.6	7.4	11.3	14.1	16.1	17.6	
Total and grand average lengths	74	—	M	—	6.9	10.9	13.6	15.5		
	89	—	F	—	7.1	11.2	13.9	16.1	17.6	
Neuse	34	II-1	M	14.2	6.9	11.0				
	2	II-1	F	15.8	6.5	12.2				
	44	III-1	M	16.3	7.1	11.5	14.4			
	19	III-1	F	17.1	6.8	11.6	14.9			
	9	IV-1	M	18.0	7.2	11.7	14.7	16.6		
	24	IV-1	F	18.3	7.1	11.5	14.6	16.9		
	27	V-1	F	19.5	7.6	11.6	14.7	16.8	18.6	
	5	VI-1	F	20.5	7.8	11.9	15.5	17.7	18.9	20.2
Total and grand average lengths	87	—	M	—	7.0	11.3	14.5	16.6		
	77	—	F	—	7.2	11.6	14.8	16.9	18.6	20.2
Susquehanna	6	I-1	M	11.1	6.7					
	4	II-1	M	12.5	6.1	10.2				
	19	III-1	M	15.2	6.7	10.8	13.3			
	20	III-1	F	16.9	6.9	11.3	14.4			
	17	IV-1	M	16.6	6.3	10.2	12.7	14.9		
	22	IV-1	F	17.9	6.8	11.3	14.2	16.1		
	4	V-1	M	17.0	6.8	10.4	12.7	14.4	15.9	
	12	V-1	F	19.3	7.0	10.9	13.8	15.6	17.5	
Total and grand average lengths	50	—	M	—	6.5	10.5	13.0	14.8	15.9	
	54	—	F	—	6.9	11.2	14.2	15.9	17.5	

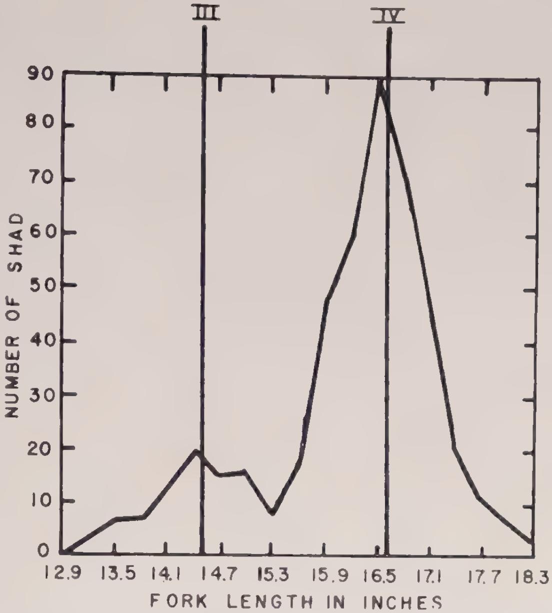

FIGURE 4.—Length-frequency distribution of 458 Neuse River shad (males) compared with mean calculated lengths at annuli III and IV.

corresponding age group at the time of capture. In all but two instances, there is fairly close agreement between actual length at capture and calculated length (Table 4). The calculated length at any annulus is closer to the actual length at capture than to any other age class. The two exceptions to this last statement are: The fork length at annulus V in Susquehanna River males and the fork length at annulus VI in Neuse River females. These samples probably were too small to calculate the average fork lengths accurately.

The first criterion was applicable to the males only from the St. Johns and Neuse Rivers. The second and third suited samples of both males and females from all three rivers. By the three preceding criteria it appears that results from aging shad from scale annuli are not in conflict with known facts about the shad and its life history.

ACKNOWLEDGMENTS

The author wishes to thank the staff of the U. S. Fishery Laboratory, Beaufort, North Carolina, who collected the field data and gave advice throughout the study and Lloyd L. Smith, Jr., Department of Entomology and Economic Zoology, University of Minnesota, for suggestions on treatment of the data.

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SOME EFFECTS OF ARTIFICIAL LIGHT ON SALMON EGGS AND LARVAE[1]

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ABSTRACT

Eggs and resulting larvae of chinook salmon *(Oncorhynchus tshawytscha)* were exposed continuously to several intensities of fluorescent light (wavelength 3350 to 6000 A. with mean of 5800 A.) for a period extending from 24 hours after fertilization through absorption of the yolk-sac. At an intensity of 157 foot-candles all eggs died before the eyed stage; at 116 foot-candles all eggs died before hatching; and at 88 foot-candles mortality from premature hatching was as much as 35 percent higher than for controls incubated in near-darkness and receiving 0.02 foot-candles. Not more than 37 percent of the eggs exposed to 88 foot-candles hatched, compared to 74 percent for the controls. Most of the larvae of the 88 foot-candle group died by the time the yolk-sac was absorbed compared to a mortality of 30 percent by the controls during a similar period. Chinook salmon eggs under artificial light hatched sooner than those in near-darkness and the larvae from the light-reared group, when compared to the controls, were more sluggish, more darkly pigmented, smaller, and slower in absorbing their yolk-sacs. Of the two experimental lots of chinook eggs, one yellow- and one orange-colored, the yellow eggs hatched more quickly.

Eggs of silver salmon *(O. kisutch)* were similarly treated. At an intensity of 157 foot-candles all eggs died before hatching and at 86 foot-candles 26.5 percent of the eggs and resulting larvae were dead by the time of first feeding. The control group had a mortality of 9 percent at the time of complete yolk-sac absorption. No difference was noted in size or activity of larvae produced from eggs incubated in light or near-darkness. As with the chinook eggs, an increase in light intensity decreased the number of temperature units required for hatching.

INTRODUCTION

Under natural conditions, salmon eggs are deposited and develop under 6 to 24 inches of gravel. During the yolk-sac absorption stage, which varies in duration with water temperature, the larvae remain in the gravel. When the yolk-sac has been absorbed, the young salmon emerge into the stream or lake and commence feeding. Under conditions of artificial propagation, the amount of light to which salmon eggs and larvae are subjected may differ considerably from that received in nature. This has led to several investigations on the effect of light on incubating eggs and newly-hatched fry.

Smith (1916) noted that eggs of both chinook and pink salmon incubated in the light hatched more quickly than those incubated in the dark. Newly-hatched fry from eggs incubated in the light were more restless and absorbed their yolk-sacs more rapidly than those from eggs incubated in darkness. He attributed the rapid absorption in the yolk-sac to the greater activity of the fish and found that fish reared in darkness had an average weight of 11 percent more than light-reared fish by the time of first feeding.

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[1] Contribution Number 37, College of Fisheries, University of Washington, Seattle, Washington.

Haempel and Lechler (1931) noted the effects of ultra-violet light upon the eggs and sac-fry of three species of trout, as well as pike *(Esox lucius)*. They found that eggs were especially sensitive to light and easily destroyed. Strong irradiation of eggs seemed to modify the yolk-sac and embryo after hatching. Freshly fertilized eggs appeared to be more resistant to light and to show fewer unfavorable effects than eyed eggs. Trout eggs of the three species seemed to differ in sensitivity to light, and brook-trout eggs were especially susceptible.

Bell and Hoar (1950) used ultra-violet radiation of 2800-3100 Angstrom units to irradiate eggs and alevins of the sockeye salmon *(O. nerka)*. Irradiation of the eggs in the later stages of development stimulated hatching. The premature alevins, which hatched a month before the controls, were abnormal in several respects. It was observed that growth was retarded, the yolk was not utilized as rapidly as in the controls, and pigmentation was delayed. The mortality was particularly high at the time of hatching and the hatching process was abnormal.

METHODS AND MATERIALS

White fluorescent tubes, eight feet long, were used as the experimental light source. Spectrographic analysis of the light from each tube after it had passed through a sheet of window glass 1/16 inch thick revealed a wave-length range of 3350-6000 Angstrom units (a range which excludes infra-red and almost all ultra-violet radiation) with a mean at approximately 5800 A. (yellow portion of the spectrum). Spectrographs taken before and after the experiment showed no change in either wave-length range or mean.

To provide different light intensities, a fluorescent fixture for one tube, two tubes, four tubes, or none was installed over each trough. The tubes were placed four inches above the water surface, and seven inches from the eggs. Between the light source and the eggs, there was placed a plate of window glass 1/16 inch thick to eliminate ultra-violet rays, and a one-layer thickness of ordinary window screen to shield the eggs from radio-waves. All glass plates were cut from the same strip, and all screens cut from the same roll of screening. The light intensity that each group received was measured in foot-candles by a Photovolt meter.

Water temperatures were recorded from a Bristol thermograph, and thermograph accuracy was verified daily by a standard Fahrenheit thermometer. Water temperatures at the inlet of the four troughs were identical at any one time but ranged during the course of the study from 55.5° to 44.8° F. No attempt was made to maintain a constant temperature. Temperatures at the outlet of each trough remained within ±0.3° F. of each other. The Williamson troughs used were painted with a non-toxic aquamarine paint and then coated with clear Tropalite paint. A water flow of 1.8 gallons per minute, from a common water source, was maintained in each trough.

Two pairs of mature chinook salmon *(Oncorhynchus tshawytscha)* were mated. The female of Pair Y produced eggs that were distinctly yellow in color. The female of Pair O produced eggs of the usual orange color. After incubation for 24 hours in total darkness, the eggs were randomly apportioned among glass-rod trays (see Fig. 1). The trays were held in place in the troughs by wooden wedges. The eggs were then subjected to light intensities of 0.02, 88, 116, and 157 foot-candles and placed as indicated in Figure 2. The eggs were continuously exposed to their respective light sources save for two to three minutes required for daily inspection of trays. During inspection, the trays received about eight foot-candles of fluorescent light.

The eggs were not disturbed until the eyed stage was reached at about

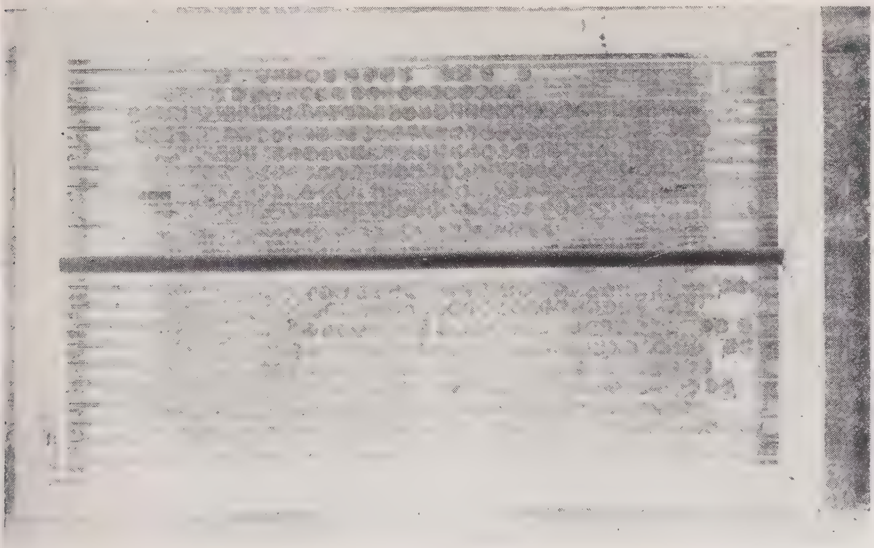

FIGURE 1.—Arrangement of salmon eggs on glass-rod tray.
(Photograph courtesy of J. R. Donaldson)

450 temperature units[2]. Mortality was estimated daily by counting the number of opaque eggs. However, since some eggs do not become opaque (due to ovoglobulin precipitation on rupture of yolk membrane) immediatly after death, stage of development was determined by use of a classification system adapted from Donaldson (1955):

> Stage I *Eggs in which the eyes of the embryo have not become pigmented nor have the fin rays appeared.* This period extends from fertilization through the closing of the blastopore.
>
> Stage II *Eggs in which the eyes of the embryo have become pigmented and the fin rays have appeared.* This stage is first apparent around 450 temperature units. During this period, the embryo continues to develop structurally until hatching time.
>
> Stage III *Eggs in which the embryo failed to survive the process of hatching.* This stage is characterized by the eruption of yolk material through a single small hole in the chorion.
>
> Stage IV *Larvae which have died during the absorption of the yolk-sac.* This stage covers the period between hatching and first feeding (from about 900 to 1700 temperature units).

At the eyed stage, the opaque eggs were removed and preserved in Stockard's solution[3]. The dead eggs were removed at 2-day intervals thereafter. After hatching, about 43 days after fertilization and at about 900 temperature units, the young were transferred to fry baskets which had been lined and divided into two equal compartments with nylon mesh. The larvae absorbed their yolk-sacs under the same light source to which they had been previously exposed. Water depth in the baskets with larvae varied from four to six inches; whereas the eggs had been under three inches of water.

In addition to the chinook salmon eggs, eggs were obtained by mating a pair of silver salmon *(O. kisutch)*. After these orange-colored eggs had been incubated in total darkness for 24 hours, all opaque eggs were removed, and the remainder randomly apportioned (in lots of 50) to form four groups of 600 eggs each. Each group was placed on a glass-rod tray, and each tray then subjected to a continuous exposure from the experimental light.

Four intensities, 0.02, 54, 86, and 157 foot-candles, were used. All other experimental conditions were the same as those to which the chinook salmon eggs had been subjected. Silver salmon eggs have a shorter incubation period than chinook salmon eggs and will reach the eyed stage at about 350 temperature units, and the hatching stage at approximately 800 temperature units.

In the chinook salmon egg study, chi-square analyses were applied to test the hypothesis that there was no difference between tray position and the number of eggs that hatched. A two-way analysis of variance technique

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[2] One temperature unit is equal to one degree above 32 degrees Fahrenheit for 24 hours.

[3] Fifty parts of 40 percent formalin, 40 parts of glacial acetic acid, 60 parts of glycerine, and 850 parts of water.

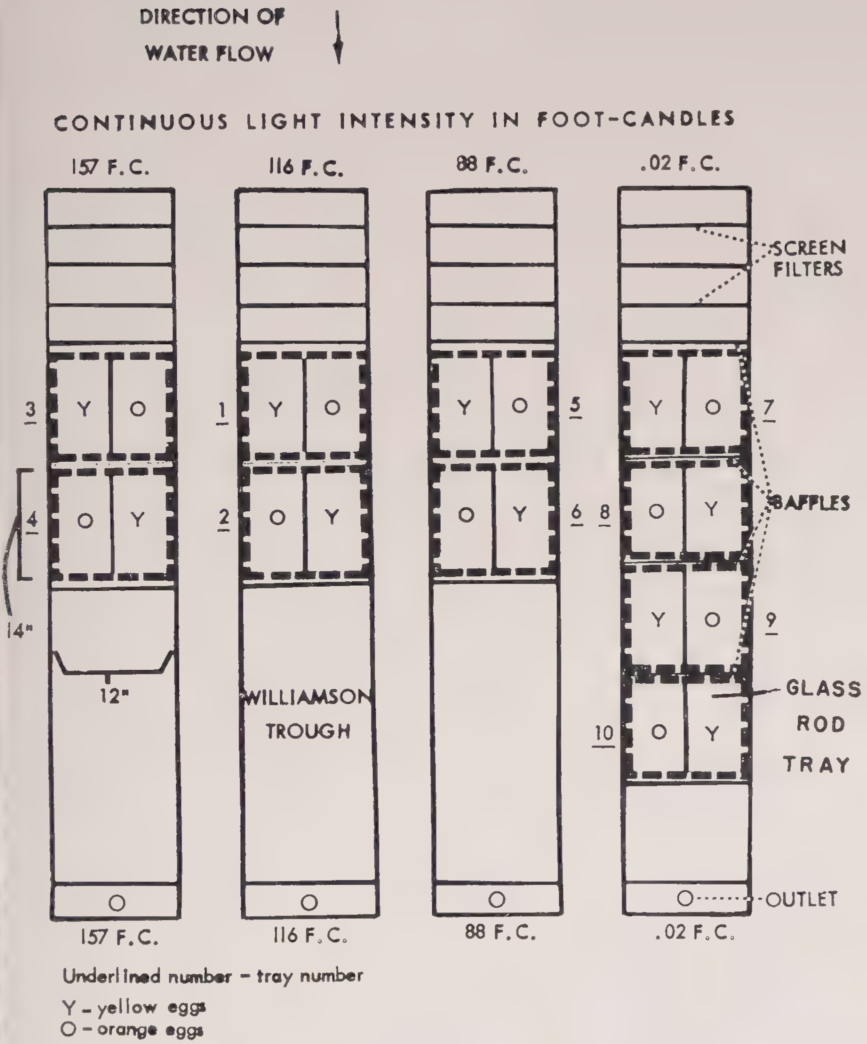
DIRECTION OF WATER FLOW
CONTINUOUS LIGHT INTENSITY IN FOOT-CANDLES
157 F.C.
116 F.C.
88 F.C.
.02 F.C.
SCREEN FILTERS
3
1
5
7
Y
O
4
2
6
8
BAFFLES
9
GLASS ROD TRAY
10
14"
12"
WILLIAMSON TROUGH
OUTLET
157 F.C.
116 F.C.
88 F.C.
.02 F.C.
Underlined number – tray number
Y – yellow eggs
O – orange eggs

FIGURE 2.—Diagram of arrangement of glass-rod trays in Williamson troughs in experiment on effect of light intensity on hatching. Fluorescent lighting tubes were placed 4 inches above water surface.

was used to evaluate relationships between light intensities, egg color, and mean number of temperature units absorbed prior to a 50 percent, or a 95 percent, hatch.

Since there were no replicates in the silver salmon experiment, statistical treatment of the data was not possible.

EXPERIMENTAL RESULTS

CHINOOK SALMON EGGS

The experiment indicated that exposure of chinook salmon eggs and larvae to fluorescent light was harmful and often lethal when exposure was continuous from 24 hours after fertilization until the larvae are ready for their first feeding (Tables 1 and 2, Figures 3 and 4). At a light intensity of 157 foot-candles, all eggs died before the eyed stage had been reached. At an intensity of 116 foot-candles, all eggs died prior to hatching. At 88 foot-candles mortality from premature hatching was as much as 35 percent higher than the control (0.02 foot-candles) groups. The physiological responses of eggs and embryos exposed to such light are unknown.

As soon as fry of the control group (0.02 foot-candle) commenced feeding, the nine surviving larvae from eggs incubated under artificial light were placed in the dark. One week later, only two light-reared fish were alive and these died within two days. The two larvae measured 25 and 26 mm., respectively; both were deeply pigmented, sluggish, and had sizeable yolk-sacs. This observation is opposed to the findings of Smith (1916) but differences in experimental conditions are sufficiently great so that a valid comparison may not be made on this point. The control group, by contrast, had a mean average length of 35.3 mm. and no excessive pigmentation. These fish swam and fed actively. During absorption of the yolk-sac, the fish reared in the light were more sluggish, and did not absorb their yolk-sacs as fast as did the control group.

It will be observed from Tables 1 and 2, and Figures 3 and 4, that there is a significant difference between trays 5 and 6 regarding the number of eggs that hatched (chi-square is equal to 57.2** for Pair Y, 55.7** for Pair 0)[4]. The reason for this difference is not known but may have resulted from a light-shielding surface film of dust and algae from the intake water. No difference was found in the proportion of eggs that hatched on trays 7-10 (chi-square is equal to 0.9 for Pair Y and 7.0 for Pair O).

Analysis of variance indicates that eggs incubated under artificial light reached the level of a 50 percent hatch (F =77.1**), and of a 95 percent hatch (F = 71.5**), more quickly than do eggs incubated in the dark. Application of the same statistical technique to differences in hatching time for yellow (Y) and orange (O) eggs indicated a faster development of the yellow eggs at the 50 percent hatch stage (F = 7.5*) and at the

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[4] **Significant at the 1 percent level; *Significant at the 5 percent level.

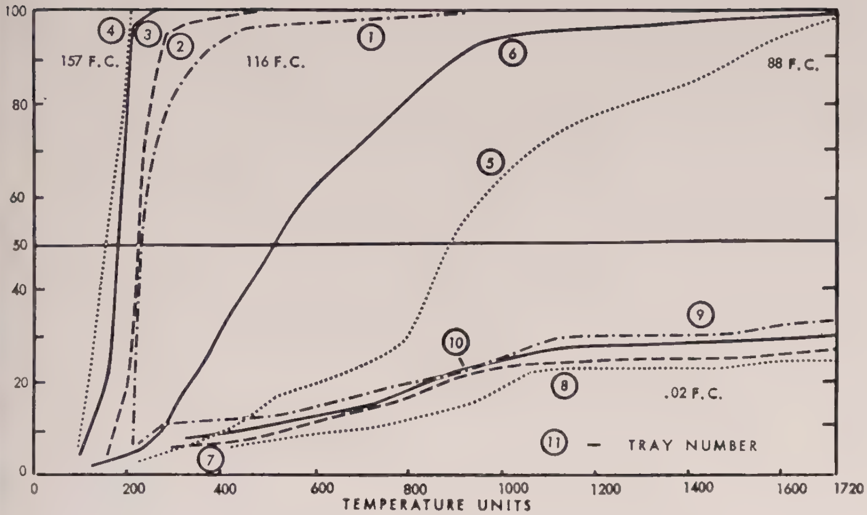

FIGURE 3.— Observed mortality of orange (Pair "O") chinook salmon eggs incubated under different intensities of artificial light and plotted against temperature units.

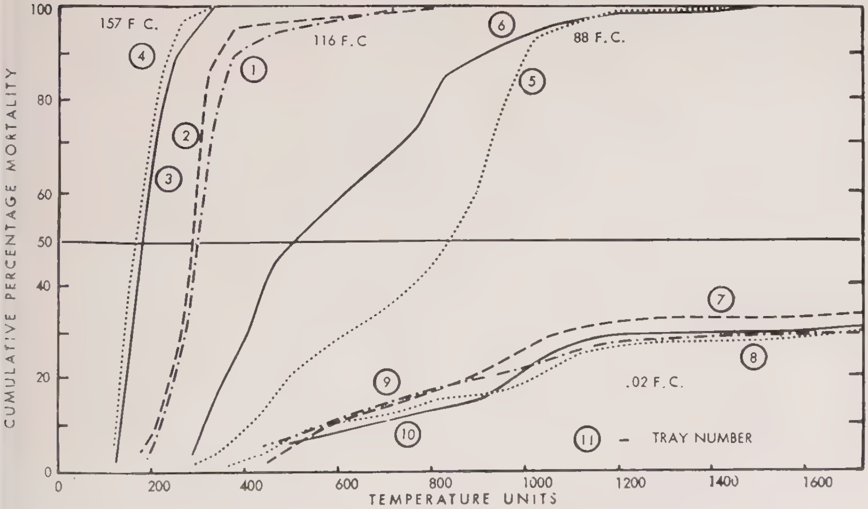

FIGURE 4.—Observed mortality of yellow (Pair "Y") chinook salmon eggs incubated under different intensities of artificial light and plotted against temperature units.

TABLE 1.—*Summary of chinook egg incubation observations—Orange-colored eggs (Pair "O")*
[For description of incubation stages see text]

Tray number	1	2	3	4	5	6	7	8	9	10
Intensity of light exposure, in foot-candles	116	116	157	157	88	88	0.02	0.02	0.02	0.02
Number of eggs in sample	438	363	483	409	405	455	445	416	390	398
Stage I mortality	414	363	483	409	96	227	86	76	101	90
Percentage	94.5	100	100	100	23.7	50.0	19.3	18.2	25.9	22.6
Stage II mortality	20	—	—	—	16	130	15	13	7	13
Percentage	4.6	—	—	—	4.0	28.6	3.4	3.1	1.8	3.3
Stage III mortality	4	—	—	—	142	61	4	1	5	4
Percentage	0.9	—	—	—	35.0	13.4	0.9	0.2	1.3	1.0
Total hatch	—	—	—	—	151	37	340	326	277	291
Percentage	—	—	—	—	37.3	8.0	76.4	78.5	71.0	73.1
Number of temperature units absorbed before 50 percent of survivors hatch	—	—	—	—	898	898	918	918	937	918
95 percent hatch	—	—	—	—	937	918	977	977	977	957
Stage IV mortality	—	—	—	—	145	36	18	17	17	13
Percentage	—	—	—	—	35.8	7.9	4.0	4.1	4.4	3.3
Total mortality	438	363	483	409	399	454	123	107	130	120
Percentage	100	100	100	100	98.5	99.1	27.6	25.6	33.3	30.2

TABLE 2.—*Summary of chinook egg incubation observations—Yellow-colored eggs (Pair "Y")*
[For description of incubation stages see text]

Tray number	1	2	3	4	5	6	7	8	9	10
Intensity of light exposure in foot-candles	116	116	157	157	88	88	0.02	0.02	0.02	0.02
Number of eggs in sample	455	555	432	524	499	476	412	437	483	496
Stage I mortality	419	547	432	524	103	198	93	91	109	109
Percentage	92.0	98.5	100	100	20.6	41.6	22.7	20.8	22.6	22.0
Stage II mortality	36	8	—	—	132	175	10	8	11	10
Percentage	8.0	1.5	—	—	26.5	36.8	2.4	1.8	2.3	2.0
Stage III mortality	—	—	—	—	134	63	13	12	8	16
Percentage	—	—	—	—	26.8	13.2	3.1	3.0	1.6	3.2
Total hatch	—	—	—	—	130	40	296	326	355	361
Percentage	—	—	—	—	26.1	8.4	71.8	74.5	73.5	72.8
Number of temperature units absorbed before 50 percent of survivors hatch	—	—	—	—	859	859	918	937	918	918
95 percent hatch	—	—	—	—	898	878	957	957	957	957
Stage IV mortality	—	—	—	—	130	40	23	19	15	16
Percentage	—	—	—	—	26.1	8.4	5.8	4.8	3.5	3.6
Total mortality	455	555	432	524	499	476	139	130	143	151
Percentage	100	100	100	100	100	100	34.0	30.4	30.0	30.8

95 percent hatch stage (F = 13.4**). One of the possible explanations why the yellow eggs hatched sooner than the orange eggs may lie in their respective light transmission coefficients. The yellow eggs, because of smaller amounts of orange-colored pigment (carotene), may have been less resistant to light penetration.

SILVER SALMON EGGS

Data for the silver salmon which were continually exposed to radiation from 24 hours after fertilization until the larvae were ready for their first feeding (about 1600 temperature units) are shown in Table 3 and Figure 5. At an intensity of 157 foot-candles all eggs died before hatching, with most of the mortality occurring simultaneously with the closing of the blastopore and subsequent pigmentation of the eyes. At an intensity of 86 foot-candles 26.5 percent of the eggs and larvae died before the time of first feeding, whereas the 0.02 foot-candle group suffered a 9.2 percent mortality during the same period.

At an intensity of 54 foot-candles 44 percent of the silver salmon eggs and larvae died before the feeding stage was reached, with most of the mortality occurring immediately after hatching. The apparent disagreement between the results of the 54 and 86 foot-candle groups may have been due to damage done the fry of the 54 foot-candle group by two young chinook salmon fingerlings that were accidentally introduced into the same

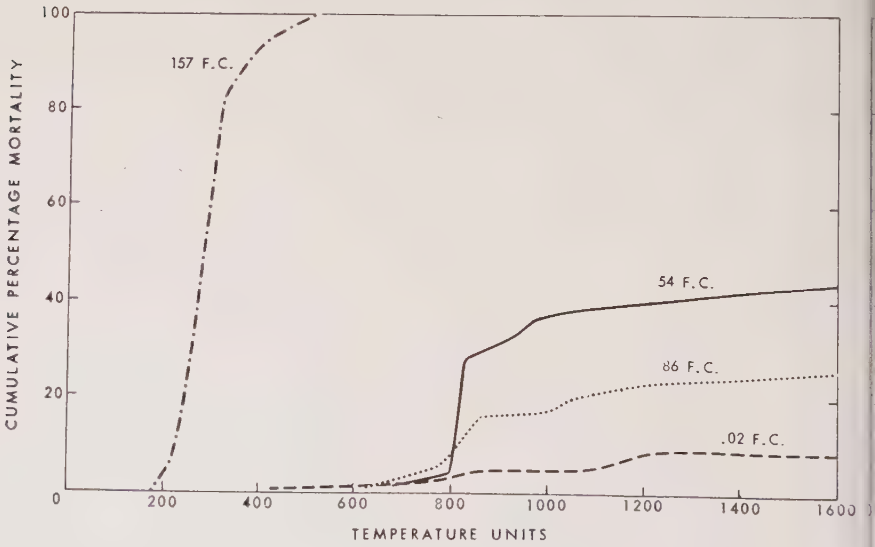

FIGURE 5.—Mortality of silver salmon eggs incubated under several intensities of artificial light, plotted against temperature units.

compartment as the silver salmon eggs at the time of hatching. The results of the 54 foot-candle group are probably not valid.

Mortality of silver salmon eggs, by stages, suggests no difference between mortalities of eggs exposed to 0.02, 54, and 86 foot-candles at the end of the eyed stage. A slightly higher percentage of eggs hatched prematurely in the light-exposed groups than in the dark-reared group but mortality among the light-reared groups increased markedly during the absorption of the yolk-sac. Whether the effects of continuous radiation are cumulative, or whether some stages are more sensitive to light than other stages is unknown.

TABLE 3.—*Mortality of silver salmon eggs incubated at different intensities of artificial light.*

[Developmental stages are described in text]

Light intensity; foot-candles	0.02	54	86	157
Number of eggs in sample	600	600	600	600
Stage I mortality	11	12	10	388
Percentage	1.8	2.0	1.7	64.7
Stage II mortality	5	6	6	212
Percentage	0.8	1.0	1.0	35.3
Stage III mortality	6	14	32	—
Percentage	1.0	2.3	5.3	—
Total hatch	578	569	550	0
Percentage	96.3	94.8	91.7	0
Number of temperature units absorbed before 50 percent of survivors hatch	794	777	777	—
95 percent hatch	811	794	777	—
Stage IV mortality	33	232	111	—
Percentage	5.6	38.7	18.5	—
Total mortality	55	264	159	600
Percentage	9.17	44.00	26.5	100

Compared to chinook salmon eggs and larvae, mortality in silver salmon eggs and larvae occurred at a relatively higher light intensity and at a comparatively later developmental stage. This may be due to a genetic difference or may be a function of the amount of light each egg received since silver salmon eggs are considerably smaller than chinook salmon eggs.

The observations indicate that the hatching time of silver salmon eggs as well as chinook salmon eggs, is related to the amount of light received, and imply that radiant energy and thermal energy have similar though independent effects on salmon eggs.

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PUBLIC OPINION ANALYSIS IN TROUT FISHERY MANAGEMENT[1]

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Abstract

An angler opinion survey was begun at Castle Lake, Siskiyou County, California, during the summer of 1957. Approximately 200 anglers were asked standardized questions in an attempt to determine how the opinions of trout fishermen about species, minimum acceptable size, and size-number balance could best be obtained. The sample of anglers was too selective to yield data of broad application. However, the technique of questioning was developed sufficiently to permit its use on a more random sample. Visual aids were used to break through prestige considerations and cliches and obtain true preferences.

Introduction

In a sport fishery the primary interest of the angler is not food but pleasure, and "pounds per unit of effort" is not in itself the important consideration. In this respect the sport fishery contrasts sharply with the commercial fishery. However, many sport fishery managers still tend to measure the success of a water by its productivity in pounds or number of fish caught. If the majority of anglers are well satisfied with the type of fishing then catch per unit of effort is a logical measure. However, this raises the question, are the majority of anglers satisfied with the type of fishing found in the particular water?

In trout water there may be three or more species which could be planted, and by proper manipulation the size factor can be varied considerably. Ordinarily this manipulation is left to the discretion of the manager. This is reasonable providing the manager knows what type of angling the majority of the fishermen want. The usual way to determine the type of management policy desired by the anglers is through trial and error. If the anglers like the fishing they will come back for more and if they don't like it the manager will be informed. However, the writers believe that through the use of standard opinion analysis methods the wishes of the anglers can be determined without the unfortunate public relations sometimes experienced when the trial and error method is used.

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[1] This work was performed as part of Dingell-Johnson Project California F-8-R, "Trout Management Study',, supported by Federal Aid to Fish Restoration funds.

The first question which arises when public opinion polling is considered is, "Whom shall we ask?" This will depend on the specific management problem at hand. If the problem is how to manage a particular body of water, the potential users of the water should be sampled. Questioning in conjunction with a creel census may not be adequate since it may draw a selected sample of those favoring the current kind of management. On the other hand, a random sample of those whom one believes to be potential users may not be practical. The question of whether the best possible sample is good enough to make a poll an improvement on the manager's guess must be answered separately for each problem.

In this paper we do not deal with the specific problem, "Whom shall we ask?" but the general problem, "How shall we ask it?" We tried to develop a technique of finding angler attitudes toward species and sizes of trout. The work was done at Castle Lake, Siskiyou County, California, as part of an intensive trout investigation. Our main interest was to discover how best to get through prestige answers and cliches to real opinions, rather than to record the opinions of the mid-summer anglers at Castle Lake.

POLLING TECHNIQUE

When social researchers attempt an investigation on a subject for which the literature is inadequate, a "pilot study" is run. According to Goode and Hatt (1952) questions during such pilot studies, "are structured very little and controlled only by dealing with those general areas (which the researcher) has reason to think important." This unstructured, exploratory questioning was done by the senior author, a fisheries biologist, and the junior author, a graduate student in social research. The senior author had explored the subject informally for several years, but had given relatively little thought to it until 1957. The junior author spent two weeks at Castle Lake prior to the standardized questioning conducting the pilot study. Unstructured, exploratory questions continued to be a part of the questioning throughout the summer.

In the beginning, we considered motivation research, the object of which would be to find out why anglers went fishing (for food, for sport, or for other reasons) and from this infer the kind of fishing which would satisfy their desires. However, a question such as, "Why did you come fishing today?" might draw a lengthy answer which would have to be handled by a well-trained and experienced researcher. On the other hand, a direct, opinion question, such as, "Do you have a favorite species of trout?" can be answered quickly and requires no extended training for the interviewer. We realized at the start that if we used the direct, rather than the indirect (motivation research) approach, we would have to let the angler balance his various desires himself and that in so doing, errors in his judgment might mislead us. If the angler has a "firm opinion" about the species he prefers, for example, then there is little danger. But if the angler is relatively inexperienced and has no structured opinion, he will be forced by our question to quickly evaluate the various thoughts he may have had about species of trout and in such a hurried calculation, errors seem likely. Without motivation research, however, we must take our chances with such miscalculations.

The pilot study led to other conclusions also. First, there are some questions which might yield reliable and valid data and there are other questions which, though important, would yield less valid answers. For example, answers to a question on the minimum size trout which an angler thinks worth taking will be affected by what size he thinks others will criticize him for accepting. His answers may also be affected by verbal cliches common to his sportsmen friends, e.g., "No fish under eight inches is worth catching," and so on. Answers to questions on species preference, on the other hand, are less likely to be affected by prestige considerations but may also be affected by cliches, e.g., "Rainbow is the native trout, I like it best", and so forth.

Following the two weeks of informal questioning, we started pretesting standardized questions in an attempt to get through the biasing factors and reach the personal opinions of the anglers. Such pretesting is a standard public opinion polling technique used to weed out, (1) questions not tapping the desired attitude, (2) questions not understood, (3) questions which offend the respondent, (4) questions which are meant to differentiate between groups of people but do not, (5) questions which are too often answered with cliches, and (6) questions which allow a respondent to fall into two different answer categories. Tabulations of the pretest results can show the need for additional questions to clear up ambiguities and may show that the relationships uncovered are not those we are really interested in.

The number of questions which can be asked in a practical length of time will vary with each situation. For example, a road-block interview would have to be much shorter than the one conducted at Castle Lake, where conditions are more relaxed and comfortable for the angler. About five minutes is not too long for an opinion interview following the routine creel check at Castle Lake. However, the length of the interview will depend on whether other anglers are waiting, how impatient or talkative the respondent is, etc.

Since our purpose was to find the best way of asking a question—to develop a technique—rather than to find out how the summer anglers at Castle Lake would vote on kinds of fishing, we changed some questions every two weeks, that is, after every 50 interviews, until we were satisfied with the questions being tested. Following was the questionnaire in use at the end of the summer of 1957:

QUESTIONNAIRE

I'd like to ask you, for the Department of Fish and Game, about what kinds of fishing you like.

1. Do you have a favorite kind of fishing?
2. How about size? Would you rather head for a lake or stream with a few big, say 15-inch trout, or one with more of the smaller, say 6 to 10-inch trout?
3. Now I'd like to ask about the smallest size fish you think worth catching. Would it give you a little pleasure to have caught this fellow (pointing to the five-incher)? (If not), This one? (pointing to the six-incher), etc.

4a. Do you happen to know what kind of trout these are? (pointing to a bottle with a rainbow, an eastern brook and a brown trout). (If yes for any of them), (b) Do you have a favorite kind of trout? (If yes), (c) How strongly do you prefer that kind of trout compared to the others, fairly strongly, or not very strongly?

5a. These cardboards, (pointing) represent different ways the Department of Fish and Game can manage trout waters. A lake or stream which will support three fish like this (pointing to the group of three) could support seven fish like this instead (pointing to the group of seven). These don't represent catches because the average catch isn't this good. Which of these kinds of fishing would you rather go fish for? (b) How strongly do you prefer that kind of fishing to the other, fairly strongly, or not very strongly?

6a. How many days have you been out fishing so far this year? (b) Do you buy a fishing license every year, or just occasionally?

7a. Have you ever been to Castle Lake before? (b) (If no), Have you heard anything about the fishing?

8. May I ask your age?
9. What is your occupation?
10. Married or single?
11. Strictly fishing, or general outing?
12. Do you have any suggestions on how we could improve the fishing in the state?

In the process of drawing up a questionnaire, some training or experience in social research is valuable. (The senior author, who had had no such training, believes this point is most important). Knowing the techniques used in attitude measurement and analysis, or at least the concepts involved in those techniques, is valuable in thinking out a problem in public opinion analysis. Some of these techniques are "attitude scaling", (Guttman, 1947); the use of the "semantic differential", (Osgood, 1957), the use of typologies and indicies (Lerner and Lasswell, 1951); the use of content analysis (Berelson, 1952); and the emphasis on conscious self-control by the observer in case-study and qualitative studies (Goode and Hatt, 1952). These techniques are listed for those interested in further study.

Pitfalls in question wording will be familiar to one with some training in public opinion polling. "The most critical need is to make sure that the issue which the questioner has in mind is the issue on which the respondent gives his answers". (Payne, 1951). An example of faulty questioning of this kind would be, "The size of fish in this stream could be increased by closing it for a year. Are you in favor of closing it for a year, or do you want to fish in it every year for fish of the present size?" The respondent who answers that he is in favor of closing the stream may simply be voting for larger fish and might rather have them at the price of a smaller bag limit or an increased license fee to allow stocking of larger fish. It would be better to ask him if he would like to have the size of fish increased by any of the possible methods, and present all of them. Another faulty question would be, "What is your favorite species of trout?" This is a loaded or leading question. It assumes that everybody has a favorite kind and such a question probably will produce more people with favorites than will our question, "Do you have a favorite species of trout?"

One technique of questioning which has become standard among pollsters is the use of filter questions. Persons who do not have enough information to have an opinion on an issue are filtered out with a fact question. For example, before asking an angler whether he has a favorite species of trout, we point to a jar containing the three common species and ask, "Do you happen to know what kind of trout any of these are?" We believe that only those who know the difference between the species can have a preference strong enough to be significant.

It is sometimes very difficult to be sure that questions are getting valid answers. One technique for checking validity is to ask a specific question covering the same opinion tapped by a general question. Another is to ask almost the same question in different words. It will be noted that our questionnaire contains two almost identical questions (Nos. 2 and 5) on preferred size-number balance.

The ordering of questions in a questionnaire also contains pitfalls for the unwary. The opening question should be one to arouse interest, perhaps asking the respondent's opinion to make him feel important. It must also allay any fears that you are going to test his intelligence or check on a possible law violation. Issues raised in early questions may influence answers to a later one. Age, marital status and occupation questions should come late.

Such considerations seem nothing but applied common sense, yet they represent the result of much trial and error in public opinion polling and social research. Public opinion analysts think of their questionnaires much as a fisheries biologist might think of his microscope; both are instruments with which a man makes observations. Neither a microscope with an unground lens nor a questionnaire with leading or ambiguous questions will resolve the problems at hand.

Discussion of Survey

The questions which were pretested at Castle Lake in the summer of 1957 fall into six broad categories: (1) exploratory questions, (2) demographic questions (age, occupation), (3) miscellaneous questions (percent of anglers visiting lake for the first time), (4) species preference, (5) size of trout considered too small to be worth catching, and (6) preferred size-number balance. The last three categories are of interest to the fisheries manager whereas the first three are routine but important parts of nearly all questionnaires.

In presenting the data from a few of the questions in the last three categories, we want to make it perfectly clear that they represent the opinions of a highly selected group of anglers. They had come to fish at one particular lake in mid-summer and we have reason to believe that their responses were not representative of those which might have been obtained at Castle Lake in the spring or fall. Similarly, they might not represent the opinions of anglers fishing any other body of water and in addition there is reason to believe that if the trout management program at Castle Lake had been different, the "type" of angler visiting the lake and consequently their responses might have been different.

Different questions have different total numbers of answers because, as previously stated, some questions were modified three or four times and a satisfactory form not hit upon until late in the summer.

Question: Do you have a favorite species of trout?

Answers:

	Number of anglers	Percent of total
No favorite	83	53
Rainbow	39	25
Eastern brook	20	13
Brown	9	6
Other trout	5	3
Total	156	

In addition to the direct question about species preference, the questionnaire contained four other questions (Nos. 1, 4c, 7b, 12) which might have elicited answers indicating a strong species preference. The anglers in our sample did not appear to feel strongly about species.

Question: Minimum size trout acceptable.

This question was asked in three ways during the summer. The last method used is, in our opinion, the most valid. In this method, we used a gallon jar of formalin and four trout of five, six, seven and eight inches in length. These were held against the glass by filling the jar with cotton. The jar could be laid on its side and rotated to show only one fish at a time. In questioning, the angler was shown the five-inch fish first and asked, "Now I'd like to ask about the smallest trout you think worth catching. Would it give you a little pleasure to have caught this fellow?" The interviewer points to the five-incher. If the angler responds, "No", the six-inch fish is shown to him and he is asked, "How about this one?", and so on, until the angler says "Yes", or until he has seen all the fish.

Question: Is this size trout worth catching?

Answers:

Minimum size trout acceptable	Number of anglers	Percent of total
5 inches or less	19	10
6 inches	85	45
7 inches	65	34
8 inches or more	21	11
Total	190	

It has been our observation that many anglers have unstructured attitudes toward fish sizes. In the first place, few can judge the size of a fish correctly in terms of inches, and secondly, their opinions about acceptable fish size are easily influenced by journalistic articles on fishing, legal limits prevailing in some states and conversations with other anglers. It appears that many have a "word concept" of size acceptablility. They may say they get no pleasure from catching a trout six inches long but when shown a six-incher, without knowing its size, they agree they would get some pleasure from catching it. Similarly this type of question is tied in strongly with pride. They may say they would get no pleasure from catching a five-incher but actually the pleasure to them might be considerable.

Another complication here is that the attitudes of anglers toward size are probably highly relative to location, kind of fishing, etc. For example, a fisherman at Castle Lake might be happy with a six-inch brook trout but would be annoyed and throw back a six inch trout accidentally caught when fishing for coastal steelhead rainbow.

Although California never has had a general minimum size limit on trout, a surprisingly large part of the anglers at Castle Lake in the summer of 1957 thought that there was a limit of six inches.

Question: Size-number preference.

In general we may say that trout fishermen fall into three categories in respect to their size-number preferences. First are those who may not have firm opinions, any trout of any size would be satisfactory, or they may not care greatly if they catch no fish. Second are those who are interested in a "mess" for eating, or want "action", regardless of size. Third are those who want relatively large fish even if they must sacrifice numbers of them. It takes little effort on the part of the fisheries manager to satisfy the first group but providing anglers with many trout, 6 to 10 inches in length, requires different management from that which would be required to provide a smaller number of big trout. It is of some importance to the manager, therefore, to know how the majority of anglers feel about these types of fishing.

It might appear that direct questions would get direct answers on these problems but this is not quite true. To begin with, the words "big" and "small", "many" and "few" are too ambiguous to have much value. We find that, here again, visual aids are very useful in obtaining valid responses. We tested cardboard models of fish and although they are helpful we believe that some type of life-like models would give a much truer visual impression. Such models may give a reasonably good idea of size but we are then faced with the problem of representing numbers. Actual size ratios of trout over six inches in length can be represented by the models. We have attempted to do this with models of different sizes grouped to give the angler a visual impression of the difference between populations which might actually be found in a "big fish" lake or stream and in a "small fish" lake or stream. This has been very helpful but it has been apparent that such models mislead some anglers. It seems difficult to present such groups of model fish without giving the impression that these represent actual catches. This, of course, could be the intention of the researcher. However, preferences based on alternative catches are unrealistic. The "average" catch does not exist. The frequency distribution of catch per angler is too skewed. Therefore, we intended to show the angler the existing population ratios of different types of water and to find out which water that angler would prefer to fish in. Thus the angler would have to take into account his ability as a fisherman, the length of time he usually fishes, what he had caught in the past, etc. He might prefer to catch one big fish but he might realize that his lack of ability could cause him to leave such a water empty-handed. In contrast, he might view the situation realistically and settle for a couple of small fish from the "small fish" water. We have found it helpful to explain that the groups of models illustrate ways in which the Department of Fish and Game can manipulate the size-number balance. We then explain that these groups do not mean actual catches but only the ratios of fish present. We believe that in most cases anglers understand and give valid responses.

Answers from the sample of mid-summer anglers at Castle Lake, which is a small fish lake, indicated that the majority was satisfied with a trout population of 6 to 10 inch fish. We tentatively conclude that this group of anglers are satisfied with the opportunity to fish for, and perhaps catch, a few small trout rather than fish long periods in the hope of catching a big one. Again let us emphasize the highly selected nature of our sample.

All public opinion polls gather some demographic data if they can. In this investigation we obtained the minimum: age, sex, marital status, occupation, and county of residence. We also asked how many days the angler had fished and whether he was a regular or an occasional license buyer. Cross tabulations may show relationships between these characteristics and angler opinions. There may also be correlations between different opinions. Finally, if it were ever necessary to make a guess about the opinions of California anglers as a whole from the results of many isolated surveys, it would probably be done through the mediation of demographic data such as those collected for the California Department of Fish and Game by the Opinion Research Center of Denver University in 1948. (DORC, 1948).

It is of some interest and importance to note that the anglers we talked to in this survey did not mind being questioned, in fact many enjoyed being consulted.

Although a survey of the literature did not disclose any similar angler opinion analyses, Van Oosten (1934) tapped the opinions of commercial fishermen in a study of the Great Lakes fisheries. He pointed out that, "The adminstrator of fisheries may at times make effective use of the questionnaire in his contact with the legislators. The legislator is as a rule highly sensitive to the sentiments of the majority and reacts accordingly." Also that, "A comprehensive questionnaire may serve, therefore, not only to guide the administrator in his recommendations on the fisheries but also to help him in making effective these recommendations and in preventing the enactment of undesirable legislation." These comments may also apply to a sports fishery.

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APPEARANCE AND FERTILITY OF TROUT HYBRIDS

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ABSTRACT

Mature hybrids among brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, rainbow trout *(Salmo gairdneri)*, and lake trout *(Salvelinus namaycush)* involving reciprocal crosses, backcrosses and three-way crosses were utilized to test fertility and to present photographic records of external charcteristics.

Fertile hybrids found among the fish tested were splake (lake trout X brook trout) and the backcross progeny of splake X brook trout. Limited fertility was found in one "tiger" trout male (brown trout female X brook trout male) and in nine yearling males originating from crosses of rainbow trout females X brook trout males. These fertile individuals have been backcrossed to the parental species with limited results to date.

INTRODUCTION

Information on the survival of F_1 hybrids between various trout species was reported by Buss and Wright (1956). These hybrids have been reared to the age of sexual maturity at the Benner Spring Research Station and observations have been made of their fertility. The objective of this study has been a continuing attempt to obtain hybrids with enough fertility to transfer desirable traits from one species to another by backcrossing.

Hybrids among brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, rainbow trout *(Salmo gairdneri)* and lake trout *(Salvelinus namaycush)* involving reciprocal crosses, backcrosses and three-way crosses have been utilized when available.

The purpose of this paper is to record the information obtained on fertility, including development of testes and ovaries. In addition, it seems desirable to record in one place the distinctive appearance of these hybrids. To this end, photographs were taken of a typical specimen of each sex of each hybrid, and appearance and fertility will be discussed. The male is shown at the top of each figure.

The trout available for testing were from two to five years of age. In almost all cases the trout could be visually sexed since the external secondary sexual characters were usually highly developed. The trout were tested by the normal expression method at intervals for eggs and sperm. and individual males and females were dissected in order to examine the development of testes and ovaries.

Even though many of these hybrid trout were only two years of age. the characteristic degree of fertility should be expressed at this age. In normal brook, brown and rainbow trout, males are sexually mature at two years of age while males and some females of lake trout X brook trout crosses are also mature at two years of age.

Appearance and Fertility

The crossing of the brown trout female and brook trout male results in the highly vermiculated "tiger" trout (Fig. 1). The testes of the males are constricted and only partially developed (Fig. 11). Some ovaries of the female contain rudimentary eggs while others remain devoid (Fig. 10). One four-year-old male from a population of 75 four- and five-year-old males had some viable sperm. This sperm was used to fertilize brook trout eggs and seven fry were hatched. These fry were lost soon after they became free swimmers.

The reciprocal cross using the brook trout female and brown trout male again produce vermiculated offspring (Fig. 2). However, in the females the vermiculations are broken up into a series of elongated yellow spots. There were no eggs in the ovaries of eight females and no sperm in the testes of one male from a group of two-year old hybrids available.

The three-way cross using the "splake" (lake trout female X brook trout male) male and the brown trout female produces a highly vermiculated progeny which resembles the tiger trout (Fig. 3). However, the bodies are slimmer and the shape of the head more closely resembles the lake trout. Of 70 two-year-old trout available, 30 were males. Dissection revealed testes and ovaries similar to those found in tiger trout, and no sperm nor eggs were found in this highly sterile hybrid.

The "brownbow" (Fig. 4), or the progeny resulting from the rainbow female and brown trout male, have the brownish cast of brown trout, but generally seem to be more spotted than the brown trout with the spots extending into the tail. The two specimens shown are exceptionally large compared to others from this cross. Only two males and eight females were available from both three- and four-year age classes; all fish were sterile with both the ovaries and the testes undeveloped.

However, Alm (1954) reported some little-known work done in New Zealand in the 1920's and described in 1949 by Stokell in which three fertile specimens from this cross were found and intercrossed successfully. Perhaps, with a greater number of fish to test, a fertile individual could be found among our hybrids.

Two large specimens of five-year old splake are shown in Figure 7 so that they may be compared with other hybrids. The high degree of fertility and detailed descriptions of this cross have been described previously (Buss and Wright, 1956; Stenton, 1950 and 1952). The growth and longevity of the splake exceeds that of any of the Pennsylvania strain of brook trout and at five years of age they are larger than the same age class of lake trout held at Benner Spring.

The backcross of splake males to brook trout females (Fig. 8) also results in fertile progeny. Two lots of backcrosses originating from individual females exhibited very different characteristics. One lot had the external appearance of the splake while the other (generally) had more of the brook trout characteristics. A few females from this latter lot were more highly colored and had larger red spotting and heavier vermiculations than is normally found in brook trout. While functional eggs and sperm are produced, the viability of the fertilized egg is generally low.

The three-way cross of splake males and rainbow females (Fig. 5) resembles the rainbow X brook trout hybrids very closely. The bodies of the former are slimmer but the large heavy spotting is very similar in both crosses. At two years of age, sixteen males and eleven females proved to be sterile. No eggs or sperm were produced and dissection revealed no eggs in ovaries and only partial development of testes (Fig. 12).

Progeny of the rainbow X brook trout cross are shown in Figure 6. Only one male and one female have been available in the two-year age class, and these fish produced neither sperm nor eggs. Very recently 72 yearlings of this hybrid were examined and nine males produced small quantities of sperm. Microscopic examination showed a number of viable sperm. Brook trout eggs have been fertilized with this sperm but tests of viability of these eggs have not been completed. If the progeny of this cross hatch and survive, it is hoped that this backcross to brook trout will permit the transfer of fast initial growth and disease resistance into brook trout without losing the identity of the latter.

Although all hybrids tested except splake show a high degree of sterility, there occur within some of these hybrids individuals which have enough fertility to warrant continued searches. Based on numbers of gametes which they are capable of producing and on the actual results observed so far, it is probable that these individuals will be found among male hybrids. They offer promise in circumventing the sterility barrier for the proposed backcross program.

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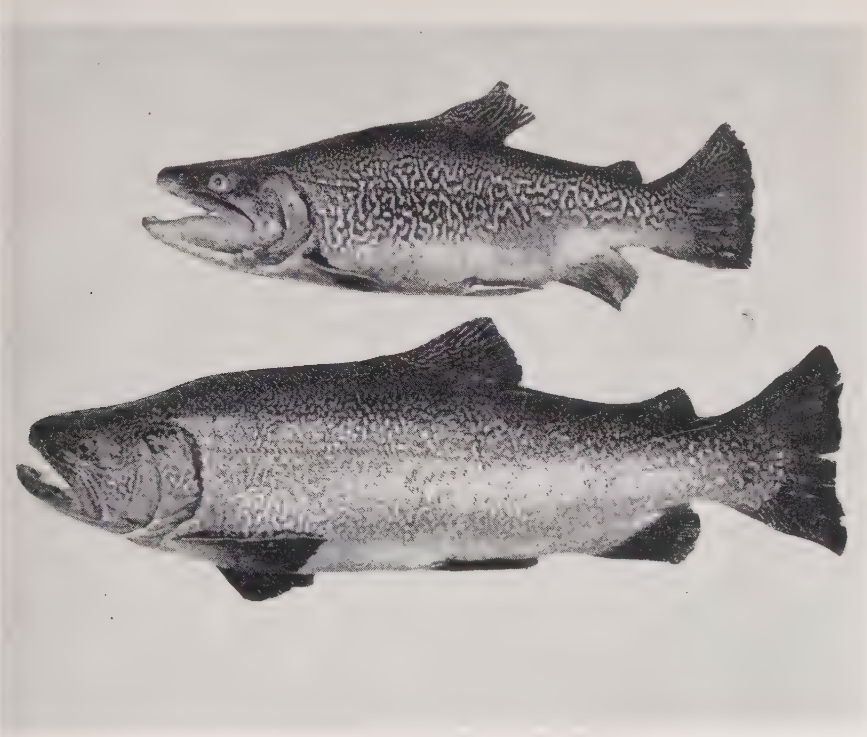

FIGURE 1.—"Tiger" trout (brown trout female X brook trout male), 5 years old. Male 21.5 inches, 5.1 pounds; female 26.4 inches, 10.2 pounds.

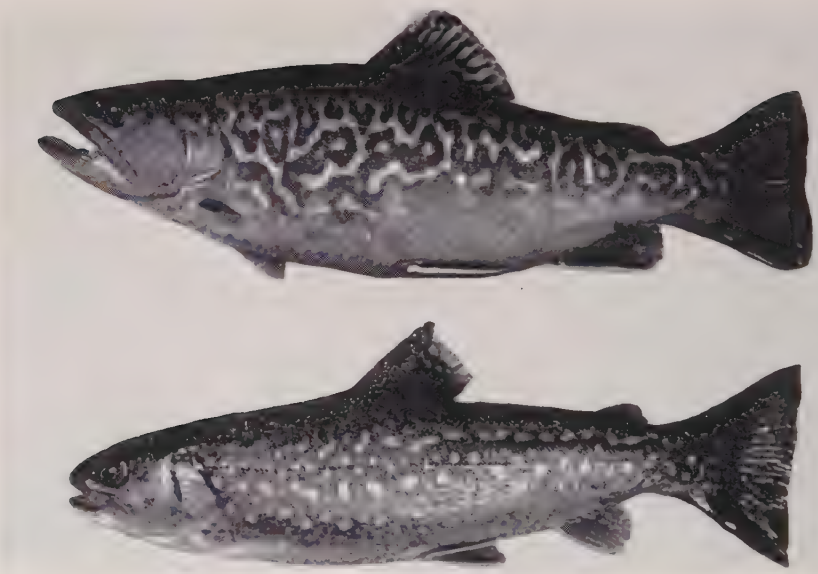

FIGURE 2.—"Tiger" trout (brook trout female X brown trout male), 2 years old. Male 11.0 inches; female 10.5 inches.

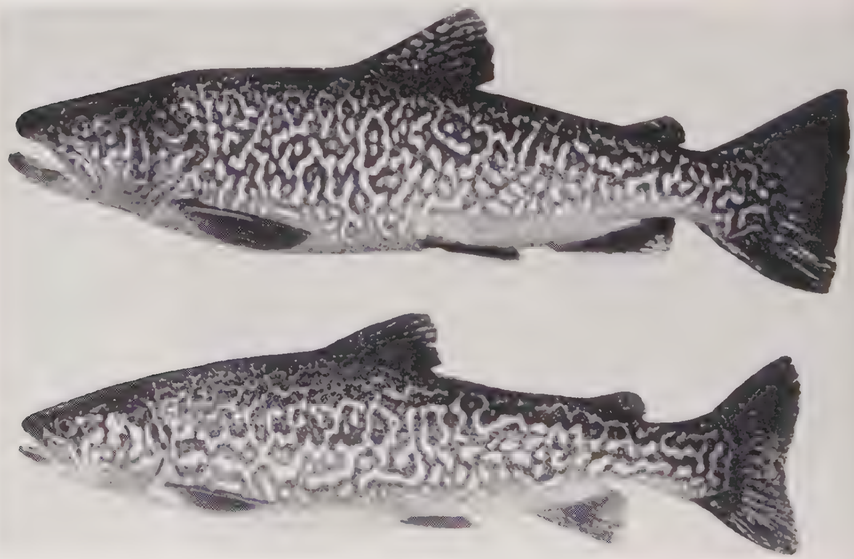

FIGURE 3.—Three-way cross of brown trout female X (lake trout female X brook male). Male 15.0 inches; female 14.0 inches.

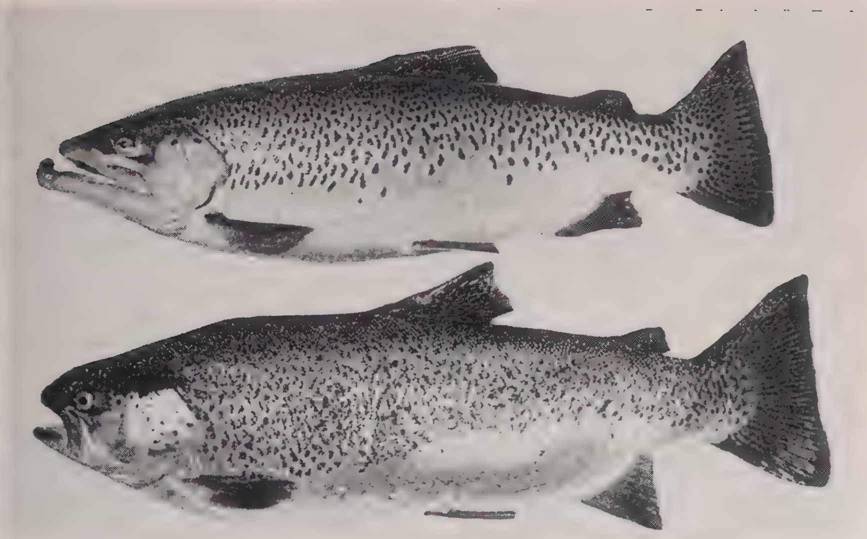

FIGURE 4.—"Brownbow" (rainbow female X brown trout male), 4 years old. Male 23.1 inches, 6.6 pounds; female 24.7 inches, 7.0 pounds.

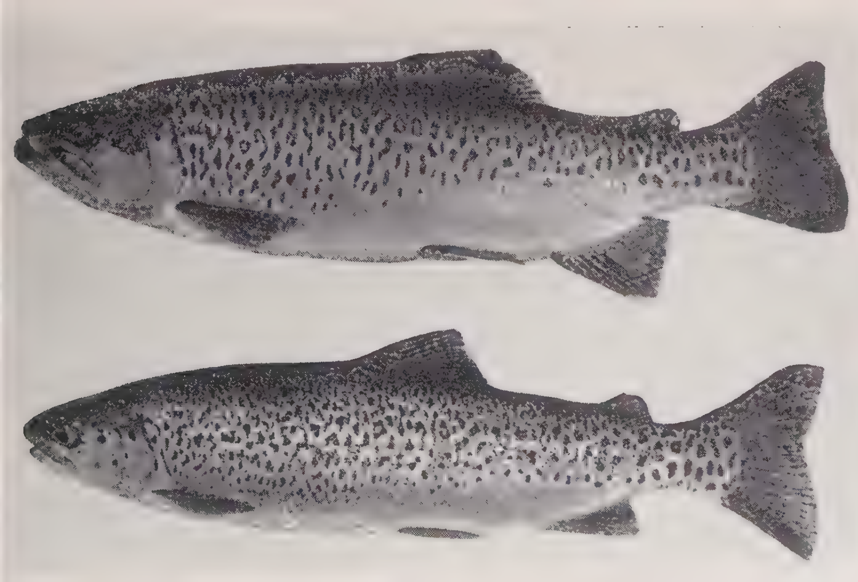

FIGURE 5.—Three-way cross of rainbow female X splake male, two years old Male 15.0 inches; female 14.5 inches.

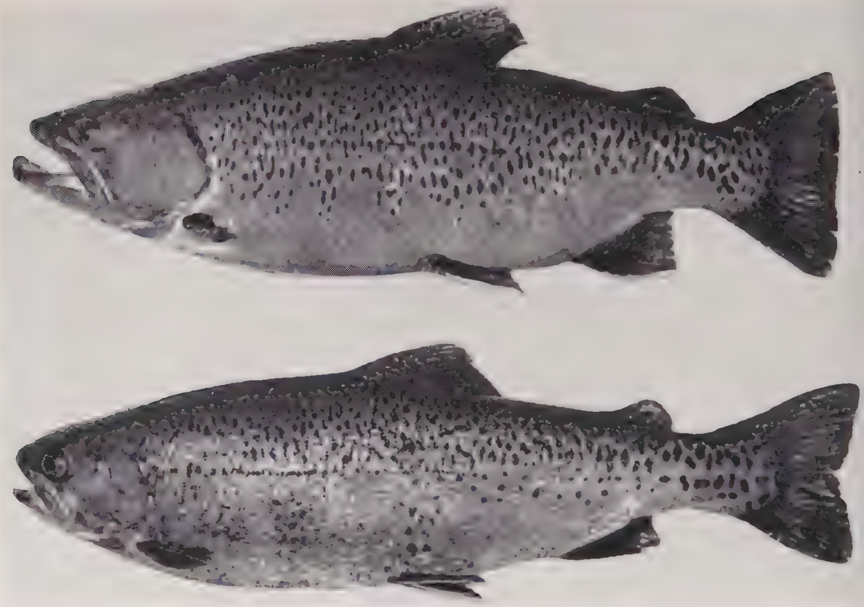

FIGURE 6.—Hybrid from cross of rainbow female X brook trout male, two years old. Male 15.0 inches; female 15.0 inches.

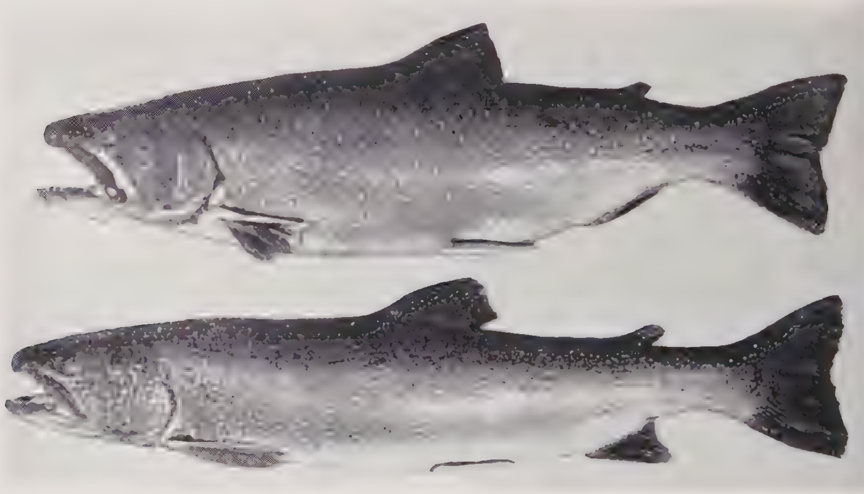

FIGURE 7.—Splake (lake trout female X brook trout male), 5 years old. Male 25.3 inches, 6.5 pounds; female 26.2 inches; 6.0 pounds.

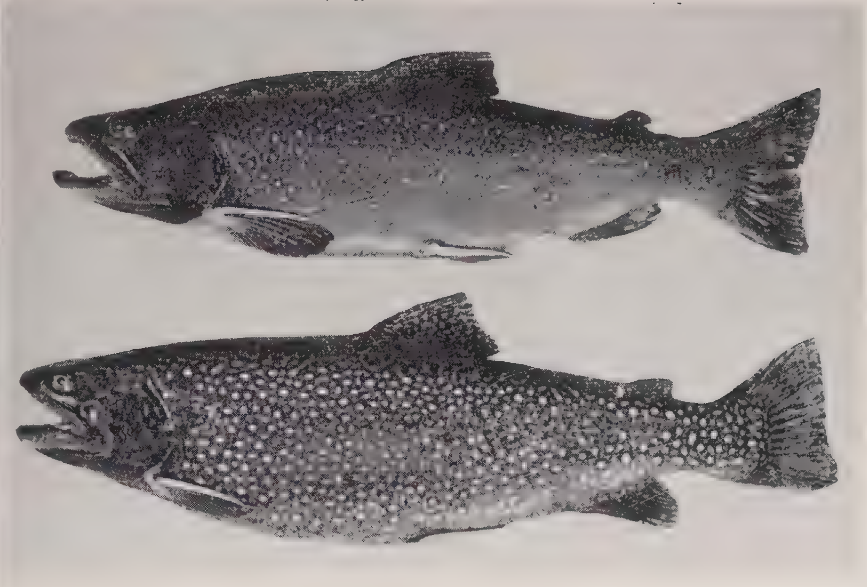

FIGURE 8.—Backcross progeny from brook trout female X splake male, 3 years old. Male 18.5 inches; female 19.6 inches. Note lake trout appearance of the male and brook trout characteristics of the female, selected from different backcross lots.

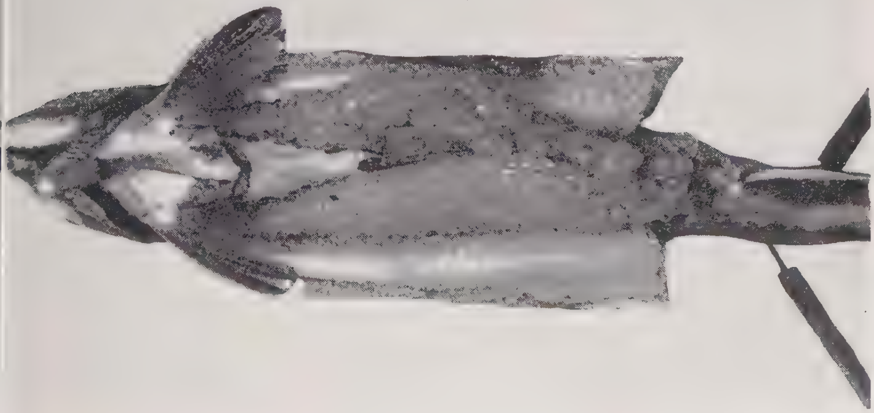

FIGURE 9.—Normal ovaries of mature brook trout. (Shown to compare with hybrid trout.)

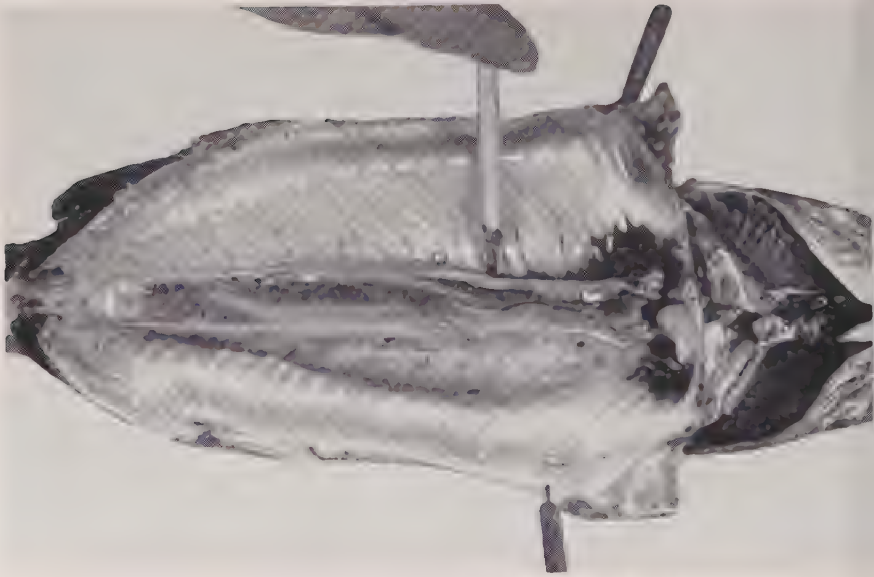

FIGURE 10.—Undeveloped ovaries of tiger trout.

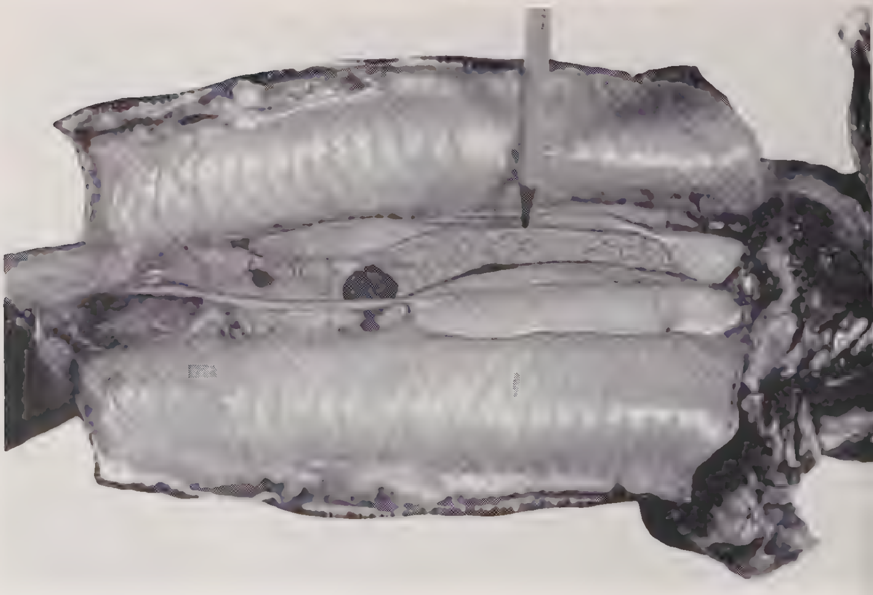

FIGURE 11.—Constricted testes of tiger trout.

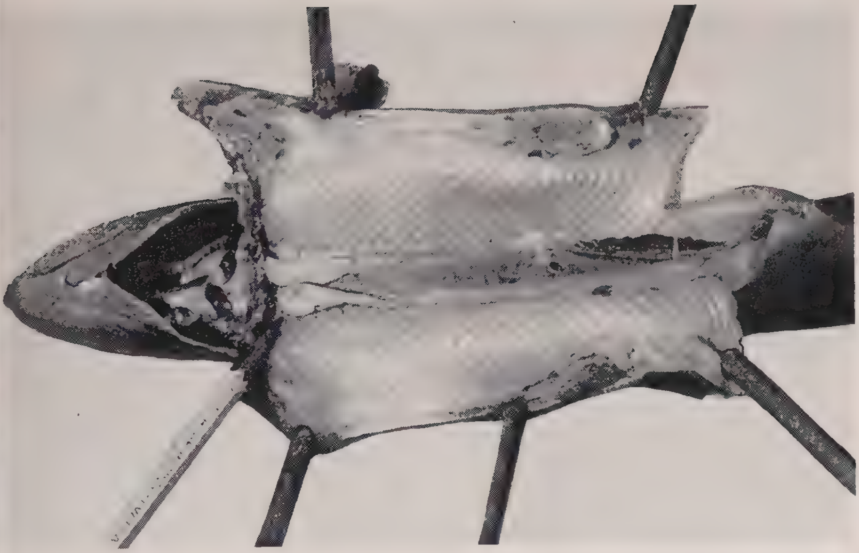

FIGURE 12.—Undeveloped testes from hybrid of rainbow female X splake male.

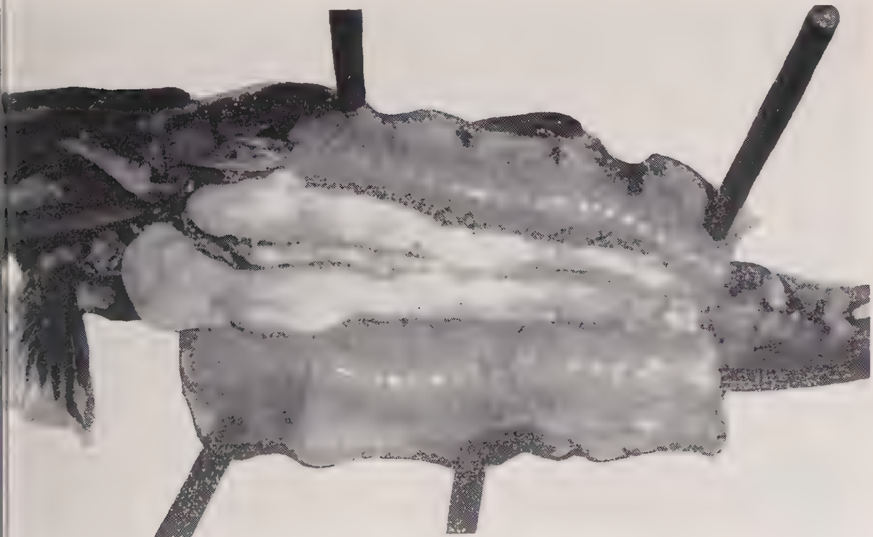

FIGURE 13.—Normal testes of mature brook trout. (Shown to compare with hybrid trout.)

OREGON'S AERIAL FISH-PLANTING PROGRAM

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ABSTRACT

Equipment is described whereby aerial planting of fish in Oregon's high mountain lakes can be done by two men. By utilizing a hydraulic loader, one man can fill the airplane transportation tank in 40 seconds. The plane need be on the ground only four minutes between flights. The aeration system described makes possible safe transportation of fry at a density of 1.75 pounds per gallon for at least one hour. Description of the equipment, results of experiments with aeration equipment, costs of operation and a brief survey of the literature are presented.

INTRODUCTION

Planting fish from the air has been recognized as a sound management tool for at least 20 years. As early as 1934, Prevost (1935) concluded that aerial stocking of lakes was not only possible but practical. Based on the results of this early work, Prevost and Piche (1939) later perfected aerial distribution equipment and procedure used in the Province of Quebec. Vestal and Lewis[2], working in California, made experimental drops of several sizes of fish from different altitudes in closed ice cream containers and by the free-fall method. They concluded that free-fall planting was most satisfactory for fish within the size range of 800 to 48 per pound and when the drop was from an altitude of 300 to 500 feet. In Olympic National Park, Washington, Garlick (1950) reported good results from using a Sikorsky helicopter for aerial planting of small lakes (five to twenty surface acres) situated at elevations ranging from 4,000 to 5,000 feet. Main advantages of the helicopter over fixed-wing aircraft was greater maneuverability, capability for slower speeds and lower altitudes over lakes as the fish are dropped, and small landing-space requirements.

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[1] Oregon State Game Commission, U. S. Fish and Wildlife Service, Oregon State College and Wildlife Management Institute cooperating.

[2] Vestal, Elden H., and Robert C. Lewis. Report on airplane fish-planting tests in Mono County, California. Bur. Fish Cons., Calif. Div. Fish and Game Rept., 8 pp. typewritten, 1946. And, Report on the second airplane fish-planting tests in Mono County, California. Bur. Fish Cons., Calif. Div. Fish and Game Rept., 9 pp. typewritten, 1947.

Leitritz (1951), describing California's airplane planting equipment and procedure, listed the following advantages of the airplane over planting by pack train: (1) Lakes can be planted early in the season before trails are open and while surface temperatures are cool; (2) fish can be placed in lakes at a time when natural food is increasing in abundance, enhancing chances for survival and growth; and (3) the time required for planting can be reduced by approximately 70 to 80 per cent over that required for pack-train stocking. Oregon workers have also pointed out the saving in equipment and personnel resulting from aerial stocking (Holloway, 1950). Loftus (1956), in describing improved fish dropping equipment used in Ontario, Canada, adds that any lake can now be effectively planted from the air and fishing acreage in inaccessible areas thereby increased.

A disadvantage of aerial stocking is that observation of the success of the plantings often cannot be made. However, numerous checks of fish survival in Oregon reveal that in the majority of instances aerial planting is successful (Holloway, 1950).

Lakes as small as one to one and one-half acres have been planted by airplane, but this is possible only when the topography will allow a safe approach and departure. Fish have been dropped from as high as 800 feet (Leitritz, 1951) and as low as 100 feet (Holloway, 1950). Leitritz (1951) reports that after release the fish have a trajectory of only about 200 feet, after which they fall straight down at approximately 28 miles per hour. Loftus (1956), however, estimated the average rate of fall of 3- to 5-inch speckled trout *(Salvelius fontinalis)* was 15 miles per hour when released at an altitude of 500 feet. Fish seem to strike the water easily and in a surprisingly short pattern. According to Holloway (1950) and Vestal and Lewis[2], the fish appear momentarily stunned but quickly right themselves and swim off in a normal manner. In small lakes they have been seen close to the shoreline shortly after the planting. One group was timed at seven minutes from the moment they hit the water until the first school appeared in shallow water.

In Oregon, planting fish by air has been practiced since 1948 when 35 high mountain lakes were stocked. In contrast, 290 lakes were so planted in 1956. Because of the growing importance of the program, equipment and procedures have been improved so that aerial planting is now an efficient and economical two-man operation. This paper describes the principal components of the Oregon program.

AERIAL PLANTING

AIRPLANE USED

The Oregon State Game Commission does not own an airplane. For aerial planting, surveys, seeding, dusting, spraying and census work, a pilot and plane are rented on an hourly or contract basis. At present a Piper PA-18-A is used for this work. The pilot and owner prefers this light airplane to the heavier bi-wing and twin-engine types because of: Low initial cost; good performance at high altitude; dependability; economy of operation; and availability of spare parts. This airplane has a load capacity of 1,010 pounds, and the estimated weight of the average load carried for planting purposes (including tank, fish, water, aeration device, pilot and fuel) is 900 pounds.

LIBERATING TANK

The liberating tank currently used is a Model 18A or Super Cub combination spraying and dusting unit, modified by separation into three compartments and installation of two 5-inch dump valves (Figure 1). The modified tank weighs approximately 80 pounds. Contents of the center unit are discharged through an internal valve and out the right exterior dump valve. Therefore, the right hand tank must be emptied before or simultaneously with the center compartment. Discharge time for either or both end tanks is four seconds, and for all three units seven seconds. Each valve is independently controlled by the pilot by use of "pull-levers" in the cockpit. Cost of liberating unit with described modifications is about $1,250.

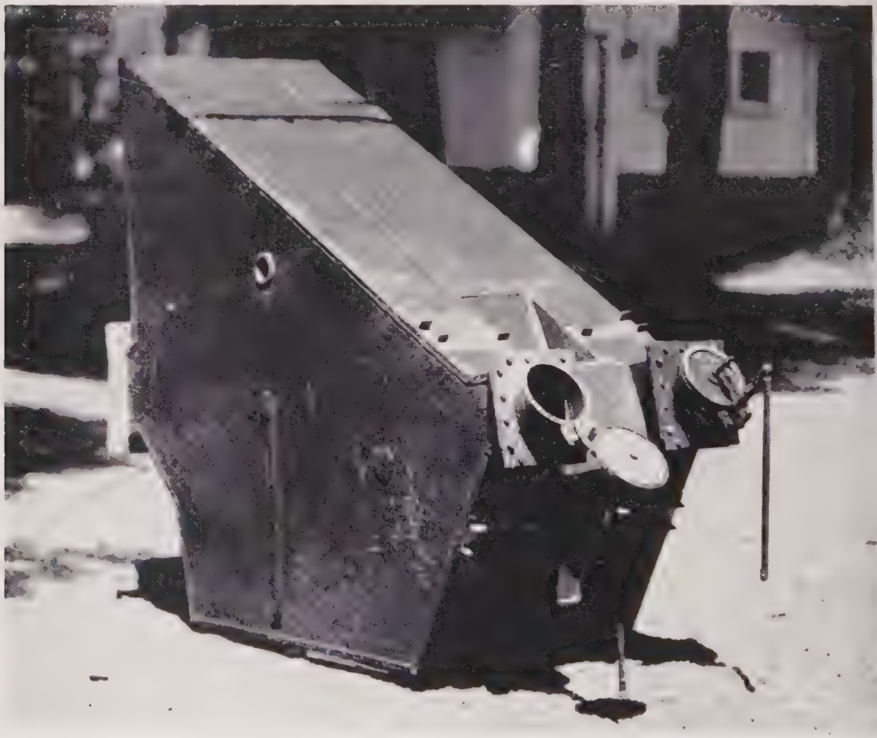

FIGURE 1.—Three-compartment air planting tank resting on its posterior surface to expose the 5-inch dump valves.

AERATION APPARATUS

The original aerating apparatus used consisted of a small electric air pump and a manifold from which an aluminum tube led to each tank. Aeration was accomplished by forcing air bubbles from 1/16-inch holes drilled in the submerged end of the tubes. Before the fish planting season of 1956, it was decided to test the efficiency of this aeration device under controlled conditions. For experimental purposes, the liberating tank used in the plane was mounted astraddle two rearing troughs at the Roaring River Trout Hatchery at Scio, Oregon. Fall-spawning rainbow trout, *Salmo gairdneri* Richardson, averaging 420 per pound, were seined from hatchery ponds for each test. All fish were starved 24 hours and no fish was used more than once experimentally. Dissolved oxygen determinations, made according to Tully's (1950) modification of the Winkler method, were made immediately after loading and at the end of each test. Losses are reported as per cent of the total number of fish.

For Test 1, the two outside tanks were filled each with 15 gallons of hatchery water. Dry cell batteries were used as a power source for the air pump. The right-hand compartment (Tank A) was loaded with fry at a density of 0.30 pounds per gallon, while the left-hand unit (Tank B) received 0.50 pounds of fry per gallon. Because the approximate maximum one-way flight time to the most remote lakes is one hour, it was intended that the fish remain in the tanks until 60 minutes had elapsed. At the end of 55 minutes for Tank A, and 35 minutes for Tank B, the fish were in such obvious distress that they were discharged. Losses in excess of one per cent in Tank A and 20 per cent in Tank B occurred. During the test run dissolved oxygen dropped from 9.40 p.p.m. to 4.00 p.p.m. in Tank A, and from 8.20 p.p.m. to 2.40 p.p.m. in Tank B.

Because the aeration device was found to be unsatisfactory for periods of prolonged transport another system was designed. The electric pump was replaced by a size "D" oxygen cylinder[3] which is 20 inches long and 13½ inches in circumference, and weighs about 13 pounds when filled with 95 gallons of gas. Oxygen is released from the tank through a pressure reduction valve or "therapy regulator[4]" which meters it accurately into the manifold. The tubes leading from the manifold into the tanks were each fitted with two spherical carborundum stones.[5]

Test 2 was performed under the same experimental conditions as Test 1 in order to check the efficiency of the new apparatus. Oxygen was supplied the 15 gallons of water in each tank at a rate of 0.40 liters per minute, and the fish were held a full 60 minutes. All fish survived. Dissolved oxygen concentrations never approached a critical level. Even at maximum density (about 2 pounds of fish per gallon), oxygen content was 11.40 p.p.m. at the end of 60 minutes (Table 1).

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[3] Product of Ohio Chemical and Surgical Equipment Company, Madison, Wisconsin.

[4] Catalog No. 8485, Ohio Chemical and Surgical Equipment Company, Madison, Wisconsin.

[5] "Ball O Mist" aerators, J. B. Maris Company, Bloomfield, New Jersey.

Load densities and rate of aeration were increased in subsequent tests without undue losses. During Test 5, considerable water escaped from a leaky dump valve in Tank A causing concentration of the fish and a 2.39 per cent mortality. Maximum load density was reached near 2.00 pounds per gallon when 7.70 per cent of the fish died during simulated transport of one hour (Table 1). This maximum load density is in close agreement with the finding of Haskell (1940) who concluded that a density of 14-2/3 pounds per cubic foot (1.95 pounds per gallon) was a tentative upper limit of tank capacity for 5½-inch brown trout *(Salmo fario)*.

In field use, this aeration apparatus has been free of mechanical breakdown. The regulator is mounted in the cabin of the airplane within easy reach of the pilot. Oxygen is turned on as soon as fish are loaded in the 15 gallons of water and shut off following release. Usually oxygen flow is regulated in direct ratio to density of the fish load. For example, if density is 0.75 pounds of fish per gallon, oxygen flow is set at 0.75 liters per minute. Because of light planting allocations for many small lakes, densities of fish in the tank rarely exceed a pound per gallon. Usually one cylinder of oxygen will last for about six hours flying time. A reserve bottle is carried in the loading vehicle and empty containers are refilled from a large commercial cylinder.

LOADING APPARATUS

Planting of fish by air has been further facilitated by the construction of a loading device that can be operated by one man. Prior to 1955 the transportation tank was loaded by pouring water and fish from ten-gallon milk cans carried to the plane on a pickup truck. The job was laborious, time consuming and required services of two men.

The basic component of the loader is the fan belt driven hydraulic hoist of the type used on snow plows. To this was added a forked lifting arm by which three fifteen-gallon tanks built into an angle-iron frame could be raised. Each tank was supplied with a hose connection. The arm, fork and tank frame were constructed at an iron works. The three 15-gallon tanks were made from grease drums. To each drum was added a metal cone and a two-inch elbow and hose for quick release of water and fish. These units were fabricated at a sheet metal company. The tanks were insulated with "Styrofoam" to maintain the 42° to 48° F. temperatures of the hatchery water.

The hoist is mounted in the forward part of the bed of a one-half ton pickup truck and bolted in for easy removal. The arm with fork is also attached by bolts. The hydraulic pump is mounted on the pickup engine and is controlled by a lever in the cab.

TABLE 1.—*Results of tests with bottled oxygen and carborundum stone aeration of tanks used for aerial transport of fish.*
[Rainbow trout weighing 420 to the pound used]

Test	Tank	Test time (minutes)	Pounds of fish per gallon	Dissolved oxygen (parts per million)		Rate aeration (liters of oxygen per minute)	Water temperature	Percent loss of fish
				Start	End			
2	A	60	0.30	6.40	6.80	0.40	50°F.	0.00
	B	60	0.50	6.70	6.20	0.40	50°F.	0.00
3	A	60	0.50	5.60	7.50	0.60	53°F.	0.00
	B	60	0.60	5.60	6.10	0.60	53°F.	0.00
4	A	60	0.75	10.80	10.30	1.00	51°F.	0.18
	B	60	1.00	9.00	6.90	1.00	51°F.	0.04
5	A	60	1.30	10.60	12.60	1.10	51°F.	2.39[1]
	B	60	1.50	10.00	13.20	1.15	51°F.	0.17
6	A	60	1.75	10.25	10.75	2.00	52°F.	0.88
	B	60	2.00	10.80	11.40	2.25	52°F.	7.70

[1] Leaky valve allowed escape of water and subsequent crowding and suffocation of fish.

During loading at the hatchery and in transport the tank frame rests on the bed and tailgate of the pickup. In loading the plane tank the three drums are lifted high enough to release the fish and water by gravity flow. The fish are hauled about 400 yards from hatchery to landing strip. Aeration system of the tanks is the same as that described for the airplane. A large tank of oxygen with regulator is mounted at the base of the tank frame for convenience and to add ballast.

Fingerling trout for stocking are held in live boxes in the hatchery ponds. Each tank of the loader is filled with approximately 14 gallons of water from a standpipe. The number of fish for each lake is weighed in a two-gallon water bucket which is then emptied into a tank of the loader. A record is made on a flight slip indicating the number, species, weight and destination of the fish in each tank.

Flight time on each trip is known and it is possible to coordinate loading so that the fish are not in the tanks over ten minutes. The truck with loader

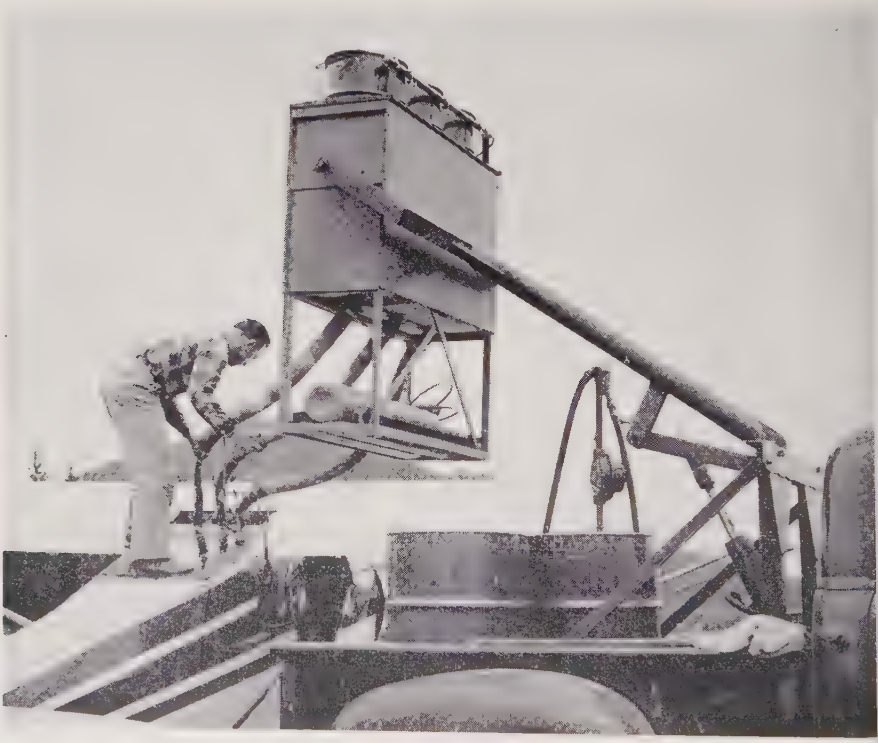

FIGURE 2.—Transferring fish from tanks of loader to tanks in plane for aerial stocking.

is driven to the airstrip to await arrival of the airplane. When the airplane lands, the pickup is backed to the aircraft. The transfer tubes from the loader are inserted by the pilot into the tanks of the airplane. The hoist is then raised to release the fish (Figure 2). Transfer tubes are replaced on the loader and the hoist depressed. The pickup is moved to the edge of the aistrip. A flight slip and aerial photo of the lakes are given to the pilot for his information.

Total loading time is aproximately forty seconds. Normal time from touch-down to take-off is four minutes. The average time for stocking fish from the hatchery pond to release in the lake is twenty-five minutes.

The average cost of planting each lake by airplane was $16.60 in 1956. The average cost of stocking a lake by pack string would be $35 at 1956 prices.

The improved aeration system in the airplane tanks and the development of the loader has provided many advantages to Oregon's air stocking operation. Individual loads of fish in the airplane have been increased 75 per cent with assurance that the fish will arrive in good condition. Through the use of the loader, the actual stocking operation requires the use of only one man and the pilot.

ACKNOWLEDGMENTS

Thanks go to personnel of the Roaring River and Fall River trout hatcheries for cooperation and use of facilities. Mr. Sam Whitney, pilot, gave enthusiastic participation to the study. Dr. H. J. Rayner and H. R. Newcomb reviewed the manuscript.

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AGE AND GROWTH OF WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL), IN BIG BAY DE NOC AND NORTHERN LAKE MICHIGAN

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Abstract

On the basis of age-composition of fish taken by commercial nets in 1949 and 1950, the whitefish in Big Bay de Noc, in the upper Michigan peninsula, appear to be a population separate from that of northern Lake Michigan. There was a change in the age-structure of the commercial catch of whitefish in Big Bay de Noc during the period 1949 to 1954. In 1949 and 1950, several year-classes made important contributions to the catch, but after 1950, Age-III fish provided 85 to 90 percent of the annual catch. Possible reasons for this change in age-structure of the catch are discussed. With the exception of two localities in northern Lake Michigan, growth rate of whitefish in Big Bay de Noc and in the lake was similar. Annual differences in growth in Big Bay de Noc were noted. Fish of the larger year-class of 1949 showed greater first-year's growth than other year-classes, suggesting that the factors responsible for good growth may also favor high survival. Whitefish of older age-groups also showed indications of greater growth during 1949 than did fish of the same age in other years.

Introduction

The relative importance of the whitefish, *Coregonus clupeaformis,* in the economy of the northern Lake Michigan commercial fisheries has varied considerably during the recorded history of the fishery. Hile *et al.* (1953) present data for the periods, 1891-1908 and 1929-1950, which show that during the earlier period whitefish made up from 1.1 to 6.6 percent of the total catch. During the latter period, however, whitefish made up 2.6 to 49.2 percent of the annual production. These wide percentage variations reflect fluctuations in production of both whitefish and other species, particularly lake herring *(Leucichthys* spp.) and suckers *(Catostomus* spp.). From 1938 to 1943, increased catch of smelt *(Osmerus mordax),* a species then becoming increasingly abundant, reduced the comparative percentages of the other species.

Annual production of whitefish in the Michigan waters of the Green Bay area, which includes Big Bay de Noc, has varied from 93 thousand pounds in 1942 to over 3 million pounds in 1948. It is of interest to note that the

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[1] Journal Article No. 2003 Michigan Agricultural Experiment Station.

whitefish which accounted for tremendous production in 1947-1949 were produced by the low parent stock of 1942 (Hile *et al.*, *op. cit.*), the young of which hatched in 1943 and became the 1943 year-class. The 1943 year-classes of lake herring and walleye *(Stizostedion vitreum)* were also unusually large, and the parent stocks of these two species were also at a low level of abundance. The phenomenal production of the three above species occurred immediately following the unexplained, catastrophic decline of the smelt population during the winter of 1942-1943. It is not the purpose of this paper to consider the relationship between these phenomena, but rather to present the results of a study of the age and growth of the whitefish in northern Lake Michigan and that part of Green Bay known as Big Bay de Noc.

METHODS OF STUDY

A study of whitefish in Big Bay de Noc was begun by Caraway (1951)[2] and continued by Barker (1953)[3], former students in the Department of Fisheries and Wildlife at Michigan State University. Samples were taken from the catch of commercial pound nets, trap nets and gill nets. Measure-

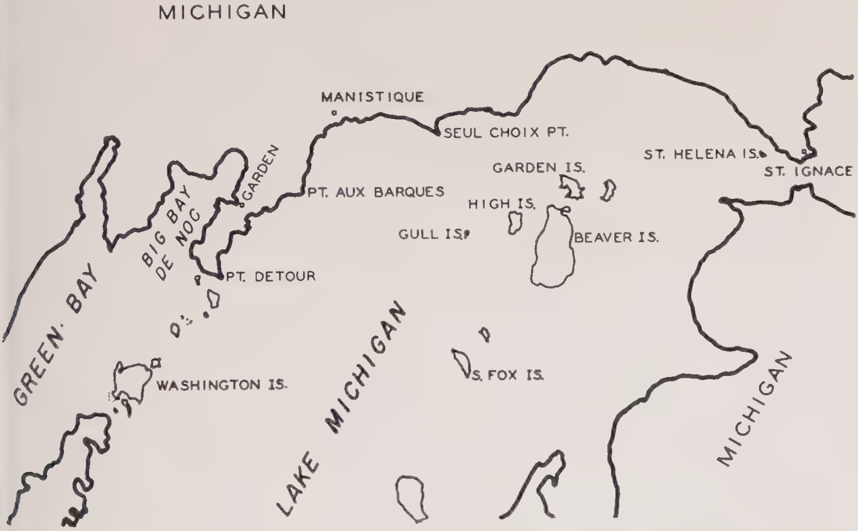

FIGURE 1.—Sketch of the northern Lake Michigan area showing location of sampling areas.

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[2] Caraway, Prentice A., The whitefish, *Coregonus clupeaformis* (Mitchill), of northern Lake Michigan, with special reference to age, growth, and certain morphometric characters. Thesis for the degree of Ph.D., Michigan State College, 1951, Michigan State University Library, microfilmed.

[3] Barker, Allan M., A study of the age, growth, and year class abundance of the whitefish, *Coregonus clupeaformis* (Mitchill), from Big Bay de Noc, Delta County, Michigan. Thesis for the degree of M.S., Michigan State College, 1953. Michigan State University Library.

ments and scale samples for later age determination were taken either on the boats or immediately upon arrival at shore installations. Measurements included total length and/or standard length, weight, and various morphometric measurements. Samples were taken at the several locations in Big Bay de Noc and northern Lake Michigan shown in Figure 1. Dates and locations of collections are given in Table 1. From the field data, information was obtained on age composition and growth rate.

TABLE 1.—*Whitefish sampels from Big Bay de Noc and upper Lake Michigan used in age and growth studies.*

Date	Locality	Gear[1]	Number of Fish	Collector
1948				
July	Seul Choix Pt.	Trap nets	102	Caraway
August	Pt. Detour	Trap nets	315	Caraway
1949				
September	Pt. Aux Barques	Trap nets	41	Caraway
Sept.-Oct.	Big Bay de Noc	Pound nets	592	Caraway
October	Garden Is.	Pound nets	25	Caraway
October	S. Fox Is.	Gill nets	86	Caraway
1950				
August	St. Helena Is.	Pound nets	45	Caraway
August	High Is.	Pound nets	174	Caraway
August	Gull Is.	Pound nets	268	Caraway
Aug.-Sept.	Big Bay de Noc	Pound nets	260	Caraway
1951				
Oct.-Nov.	Big Bay de Noc	Pound nets	167	Barker
1952				
September	Big Bay de Noc	Pound nets	127	Barker
1953				
Sept.-Oct.	Big Bay de Noc	Pound nets	641	Skinner
1954				
Oct.-Nov.	Big Bay de Noc	Pound nets	454	Norcross

[1] Trap nets and pound nets with 4½-inch stretched mesh in "crib" or "pot"; gill nets with 4½-inch stretched mesh.

AGE COMPOSITION OF THE COMMERCIAL CATCH

In gathering the data, some of the samples included all the fish caught, sublegal (shorter than 17 inches) as well as legal-sized fish. These samples contained a higher proportion of the younger age-groups than actually appear in the commercial catch. In adapting the data for this paper, the length-frequency data were used to determine the percentage of legal fish among these age-groups, and the figures presented here represent only those fish large enough to be sold in the commercial market.

The age-composition of the commercial catch from several localities in 1949 and 1950, based on data from Caraway *(op. cit.)*, is shown in Figure

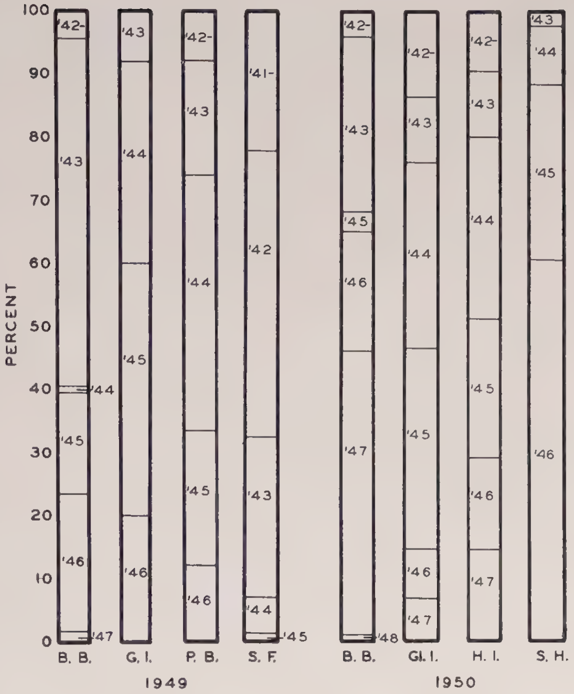

FIGURE 2.—Year-class distribution of catches of legal-sized whitefish (over 17 inches) from several areas in 1949 and 1950. B. B., Big Bay de Noc; G. I., Garden Island; P. B., Pt. Aux Barques; S. F., South Fox Island; Gl. I., Gull Island; H. I., High Island; S. H., St. Helena Island.

2. In the 1949 data there is a striking difference between the age-composition of the catches from Big Bay de Noc and the other areas. Especially noteworthy is the strong 1943 year-class and the weak 1944 year-class in the Big Bay de Noc catches, and the relatively strong 1944 year-class in both the Garden Island and Pt. Aux Barques catches. The application of chi-square tests for homogeneity show highly significant differences ($P < .0005$) between the age-structure of the 1949 Big Bay de Noc catches and those from the other two areas. The sample from South Fox Island contained more older fish than the samples from the other localities. This difference may in part result from selectivity of the gear used, but evidence will be presented to show that the difference in age-composition of the catch may be attributed to differences in growth rates.

The age-composition of the 1950 samples from Big Bay de Noc also differs significantly from that of the Gull and High Island areas in Lake Michigan ($P < .0005$). The 1943 year-class made up a substantial portion (about 28 percent) of the Big Bay de Noc catch, although three-year-old fish (1947 year-class) provided nearly one-half of the catch. The 1944 year-class, prominent in catches from the Gull and High Island areas, was lacking in catches from the Bay. Except for the prominence of the 1943 year-class in Big Bay de Noc catches, the St. Helena Island catches exhibit an age-composition similar to that of the Bay.

The above data indicate that there were at least three, and possibly more, separate stocks of whitefish in the Big Bay de Noc-northern Lake Michigan area during the study period. However, there is strong evidence that the large Big Bay de Noc population of the 1943 year-class did not remain entirely within the Bay. Samples taken by Caraway *(op. cit.)* from catches off Pt. Detour and Seul Choix Pt. in July and August, 1948, show that the 1943 year-class was prominent at Pt. Detour but was not present in unusual numbers at Seul Choix Pt., about 40 miles northeast of Pt. Detour. The 1949 data indicate that fish of the 1943 year-class were present, but not prominent, in the Pt. Aux Barques fishery which adjoins the Pt. Detour fishery. It is reasonably sure, therefore, that whatever conditions favored the production and survival of the 1943 year-class in Big Bay de Noc were not present in much of northern Lake Michigan, and that there is little or no mixing of the populations of the Bay and the Lake except during periods of high population density, and then only to a limited degree.

Data for the years 1949-1954, as shown in Figure 3, illustrate an abrupt change in the age-structure of the Big Bay de Noc whitefish population following the disappearance of the 1943 year-class from the fishery. In 1949 and 1950 the fishery took at least three year-classes in substantial amounts, but in following years the catch was composed chiefly of three-year-old fish. Conclusions from these data agree with recollections of commercial fishermen who remember 1950 as the "last year of the jumbo whitefish", indicating that former catches contained more larger and older fish than have been taken in recent years. The dependence of a fishery on a single age-group of fish each year, three-year-old fish in this case, seems to be precarious. A spawning failure in any given year must result in a serious decline or collapse of the fishery three years later. Evidence of spawning failure in the Green Bay area in 1952 and 1953 is provided by the catches of 70,000 and 11,000 pounds of whitefish in 1955 and 1956 respectively. These catches, compared with a catch of over 3 million pounds in 1949 represent a catastrophic decline.

If the age-structure described for 1951-1954 is a recent development, one must consider three possible reasons for the change: (1) migration of the older fish out of Big Bay de Noc; (2) increased fishing mortality of the older fish; and/or (3) increased natural mortality of fish older than three years.

Migration of large fish out of Big Bay de Noc can probably be discounted as a major cause of the change because the age-composition studies

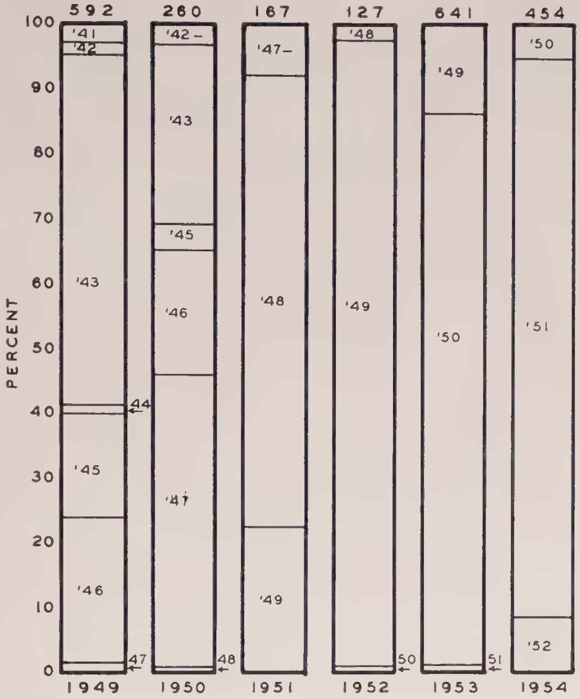

FIGURE 3.—Year-class distribution of catches of legal-sized whitefish (over 17 inches) from Big Bay de Noc, 1949-1954.

indicate that the Big Bay de Noc population does not mix appreciably with those of adjoining areas. However, this conclusion is based on data obtained prior to the change in age-structure. Results of a tagging study in 1954 and 1955 in Big Bay de Noc by Norcross (unpublished) also indicate little migration of Big Bay de Noc whitefish into Lake Michigan; only one of 209 tag returns was from Lake Michigan proper and the rest from the Green Bay-Bay de Noc area.

If there was no appreciable migration of older fish out of Big Bay de Noc, their virtual disappearance from the catch must be attributed to increased mortality (fishing or natural) of age-III fish. An estimate of total mortality between age III and age IV may be obtained by analyzing the age-structure of the catches from 1951-1954 and using the following equations: (1) $s = Y_{IV} / Y_{III}$; and (2) $r = 1\text{-}s$: where s = survival, Y_{IV} = percent of age-IV fish in the catch, Y_{III} = percent of age-III fish in the catch, and r = total mortality. Table 2 presents the age-structure of the catches in 1951-1954 and shows the method of calculating the survival. The mean survival rate of whitefish from age III to age IV for the years 1951-1954 approximates 0.06 or 6 percent. The mean annual mortality of age-III fish during this period then approximates 0.94 or 94 percent.

From available data there is no method of determining the proportionate values of fishing mortality and natural mortality in Big Bay de Noc. Dr. Ralph Hile, in a personal communication, has provided data regarding the amount of gear used in the Michigan waters of Green Bay for the years 1943-1954. The amount of fishing effort since 1950 has never exceeded 50 percent of that of the years of peak yield (1947-1949) when fish of age IV and older were prominent in the catch. There has been no known change in the efficiency of the gear or in fishing methods during the period of consideration. It is therefore difficult to attribute the change in age-structure to increased fishing mortality of the older fish.

TABLE 2.—*Age-structure of Big Bay de Noc whitefish catches, 1951-1954, showing survival and mortality.*

Column	A	B	C	D	E	F
Year	Number of fish	II	III	IV	Survival (s) D/C	Mortality (r) 1-E
		percent	percent	percent		
1951	167	22.0	70.0	2.7	0.039	0.961
1952	127	0.8	97.6	1.6	0.016	0.984
1953	641	1.0	85.0	14.0	0.165	0.835
1954	454	9.0	87.7	3.3	0.038	0.962
Total					0.258	3.742
Mean					0.064	0.936

There is some admittedly inadequate evidence of increased natural mortality of the larger whitefish. Commercial fishermen in the area report that after periods of strong winds, especially from the southwest, they frequently find large numbers of dead whitefish in varying stages of decomposition in their gill nets. It is suggested that dead fish or fish in weakened condition are moved into the nets by wind-generated currents. Such fish are reported to be of commercial size and show a high incidence of sea lamprey scarring. This situation has not been witnessed by biologists, but personal acquaintance with some of the reporting fishermen lends credence to their statements.

GROWTH RATE

Because the collections of Caraway (1951) were made throughout the fall months when whitefish are growing, growth rates presented are based on back-calculation of lengths at time of annulus formation rather than on lengths at time of capture. Comparisons of growth rate between the various areas are based on fish of the same age (age IV) to avoid the effect of Lee's phenomenon, which is exhibited to a marked degree in some of the collections (the calculated length at age I varies as much as 39 millimeters between fish of age II and age V).

The growth data adapted from Caraway *(op. cit.)* are shown in Table 3, which also includes data adapted from Van Oosten and Hile (1949) for Lake Erie and Lake Huron. Growth was slowest in the South Fox Island area and fastest in the St. Helena Island area, but there was little difference in growth of whitefish from the other locations in northern Lake Michigan. On the basis of the data at hand, the growth in Lake Huron appears to be somewhat slower than in northern Lake Michigan. The Lake Erie whitefish show a more rapid growth during the first two years, but much of this initial advantage is lost by the slower growth beyond age III.

Table 4 presents growth-data adapted from Caraway (1951) and Barker (1953) for Big Bay de Noc. The growth rates are based on age-III fish inasmuch as age-IV fish appeared in extremely small number in the samples of 1951 and 1952. The 1949 year-class was considerably stronger than the three previous year-classes (Barker, 1953). These fish also grew at a rapid rate, many of them reaching legal size (17 inches) before attaining age III.

TABLE 3.—*Average calculated total lengths (millimeters and inches) of age-IV fish from Big Bay de Noc and northern Lake Michigan, 1949, 1950, with some comparative data from Lake Huron and Lake Erie.*

Year of Capture	Locality	Number of Fish	Total Length							
			I		II		III		IV	
			mm.	inches	mm.	inches	mm.	inches	mm.	inches
1949	Garden Is.	10	145	5.7	253	10.0	355	14.0	451	17.8
	Pt. Aux Barques	8	124	4.9	250	9.8	368	14.5	462	18.2
	S. Fox Is.[1]	77	108	4.3	177	7.0	251	9.9	335	13.2
	Big Bay de Noc	28	130	5.1	250	9.8	358	14.1	456	18.0
1950	High Is.	23	138	5.4	230	9.1	325	12.8	431	17.0
	Gull Is.	21	131	5.2	221	8.7	313	12.3	424	16.7
	St. Helena Is.	12	171	6.7	268	10.6	376	14.8	470	18.5
	Big Bay de Noc	60	143	5.6	239	9.4	350	13.8	455	17.9
	Lake Huron[2]		127	5.0	266	8.9	312	12.3	409	16.1
	Lake Erie[2]		175	6.9	323	12.7	409	16.1	460	18.1

[1] Based on ages VI to VIII.

[2] Adapted from Van Oosten and Hile (1949); based on whitefish of ages I-XII.

Thus the 1949 year-class, made up of large numbers and of large individuals, suggests that conditions which favor growth also favor survival.

Factors determining survival of fish and establishment of year-classes have long been a subject of thought and discussion by biologists. Hart (1930) reviews the effects of some of these factors in his study of whitefish in the Bay of Quinte, Ontario. While he was not able to determine exactly the extent of mortality of eggs on the spawning ground, he feels that there is a heavy mortality during this period. He also found heavy predation of whitefish eggs by yellow perch, *Perca flavescens.* ("Twenty-one specimens ranging in length from 18 to 25 cm. (7 to 10 in.) examined Nov. 2-7, 1926, all contained whitefish eggs, averaging over 200 eggs per fish.") Another critical factor mentioned by Hart is the food available to fry immediately after absorption of the yolk sac. If food is lacking at this period, mortality will be high. Food, however, might be available for fry, allowing good survival, but be scarce during the remainder of the first year of life, resulting in mortality and/or slow growth.

The history of the 1949 year-class of whitefish in Big Bay de Noc indicates that both survival and growth were above average, and suggests that perhaps the entire first year of life, rather than just a short period after hatching, represents a critical period.

TABLE 4.—*Average calculated total lengths (in millimeters and inches) of four year-classes of whitefish taken in Big Bay de Noc at age III, with percentage increase in growth.*

Year-class	Number of fish	Total length at given age						Percent increase in growth between years	
		I		II		III			
		mm.	inches	mm.	inches	mm.	inches	I-II	II-III
1946	37	149	5.9	256	10.1	377	14.8	72	47
1947	124	145	5.7	266	10.5	394	15.5	83	48
1948	28	155	6.1	285	11.2	400	15.7	84	40
1949	124	172	6.8	299	11.8	406	16.0	74	36

As shown in Table 4, the conditions responsible for the first year's growth of the 1949 year-class also appears to have favored growth of the older fish during the same year. In 1949, fish of the 1948 year-class had a larger average growth between age I and age II than did fish of other year-classes; and fish of the 1947 year-class, between ages II and III, had a greater average growth than those of other year-classes of similar age. The 1946 group reached age III before this period of good growth and was shorter at age III than were the later year-classes. Some of the differences, however, are more indicative than conclusive.

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MANAGEMENT OF SPORT FISHING IN SAN DIEGO'S PROGRAM OF MULTIPLE USE OF WATER-SUPPLY RESERVOIRS

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Abstract

Multiple use program of eight San Diego, California water-supply reservoirs includes closely regulated sport fishing for warm-water fish. These reservoirs, when full, supply about 8,000 acres of fishing water on which there were 105,000 fishing trips in 1956 by which 456,000 fish were taken. Average catch has been 6.2 fish per fishing trip. The program is under the supervision of the San Diego Water Department and to protect public health, access to reservoirs is permitted only at stations manned by Water Department personnel. Here, public facilities including toilets, boats, trash cans, fishing docks, fireplaces, and parking areas are maintained. Regulations pertaining to protection of public health are strictly enforced. The recreational program, which includes camping, picnicking and hunting as well as fishing, is operated on a self-sustaining basis and without cost to water users through a fee-permit system. The fee for sportfishing is $1.00 a day. Close cooperation is had between the Water Department, Public Health and Conservation agencies and the public. No case of waterborne infection has been traced to pollution of the reservoirs despite many years of multiple use.

Introduction

The Water Department of the City of San Diego, California, has been involved in the development, supervision, and administration of a reservoir recreational program since 1912. At present, over a million Southern California sportsmen have the opportunity to prevail themselves of a multiple use program on municipal water supply reservoirs; a program that features fishing, hunting, camping, and picnicking.

Development of this "fishing in the drink" concept has presented many problems. Health and sanitation requirements of both the State and County Departments of Public Health had to be met and satisfied. To do this, recreational users of the reservoirs are supplied with facilities such as access roads, camping and picnic areas, concession service, showers, boats, fishing floats, and many other necessary improvements. Expenditures for recreational facilities, maintenance, and all operations pertaining to fishing and hunting are made without expense to municipal water consumers. An active public relations program is necessary so that current fishing and hunting information and associated matters can be forwarded promptly to the local sportsmen. Both the welfare of the fish populations and the recreational needs of the patrons require constant surveillance and service.

There is a great need for fresh water fishing opportunities in arid regions such as San Diego County where there are no natural lakes or permanently running streams. Here, most of the rain falls during the spring, and the average annual rainfall is about 10 inches along the coast and about 30 inches in the mountains. Runoff impounded in the reservoirs is now used mostly for a domestic supply serving over a half million City residents. In the San Diego area practically all of the fresh water angling opportunities are to be found at these water-supply reservoirs, or "City lakes."

The San Diego Water Department feels that a multiple use program for its reservoirs is a source of civic betterment. However, those who administer the recreational activities must keep in mind that the primary responsibility of the Water Department is to supply its consumers with an ample and safe supply of drinking water. Obviously, the recreational program must function without interfering to any extent with the primary reservoir use. There are psychological aspects of the multiple use program that are important. Residents of the area have been made aware that "fishing in the drink" is a unique privilege; a privilege that necessitates a stringent set of regulations which requires that their conduct on the reservoirs will not endanger the welfare of the public.

The Impounding System

Private reservoir development began in San Diego County before 1900. At that time the impounded water was used primarily for irrigation, and sportsmen were permitted unrestricted access. Regulations pertaining to public health were not then considered necessary because the municipal water supply came from underground sources. Initially, water was delivered to local consumers by private water companies and later by the City. By 1912, San Diego outgrew its underground water supply, and municipal acquisition of certain private reservoirs became necessary. The private reservoirs were purchased by the City of San Diego between 1912-1925, and consequently, the multiple use practice was literally inherited. In addition, five of the dams now present were built at later dates by the San Diego Water Department.

The Department now maintains and manages eight major storage reservoirs in the County with a combined capacity at full storage of over 427,000 acre feet. At this level, individual reservoirs have from 138 to almost 1800 surface acres of water. Their use by fishermen and duck hunters from year to year is dependent upon the amount of water impounded and other factors related to their primary use. During an average season, anglers are permitted access to approximately 4,000 surface acres of reservoir, about half the total fishable water. Fluctuations in water level during a normal operational year vary from about 15 to 50 feet.

The dams are located in three major watersheds. Since rural San Diego County is sparsely populated, pollution within these watersheds is not a present problem. The impoundments which supply water directly to the consumers via filtration and chlorination plants and the distribution system are classified as "terminal reservoirs." Such terminal reservoirs must receive greatest consideration with respect to sanitation when and where the public is permitted to hunt and fish. Two of these terminal reservoirs now receive imported Colorado River water from the Metropolitan Water District of Southern California. "Non-terminal reservoirs" impound water for transfer either to another non-terminal facility or ultimately to a terminal reservoir.

PRESENT PROGRAM

Fishes of the San Diego impoundment system are typical warm-water species and include largemouth bass *(Micropterus salmoides)*, bluegill *(Lepomis macrochirus)*, green sunfish *(Lepomis cyanellus)*, white crappie *(Pomoxis annularis)*, black crappie *(Pomoxis nigromaculatus)*, brown bullhead *(Ameiurus nebulosus)*, white catfish *(Ictalurus catus)*, and channel catfish *(Ictalurus punctatus)*. The golden shiner *(Notemigonus crysoleucas)*, mosquitofish *(Gambusia affinis)*, and the recently introduced threadfin shad *(Dorosoma petenensis atchafalayae)* are the non-game species present. None of these fishes are native to the area. The absence of carp *(Cyprinus carpio)* or any other undesirable fish species in the reservoirs used for fishing at the present time is due principally to the strict control measures regarding the use of minnows for live bait. This regulation designed and enforced by the Water Department permits only the mudsucker *(Gillichthys mirabilis)* and killifish *(Fundulus parvipinnis)*, which is sometimes known as the "salt water chub," to be used as live bait in any of the City lakes. Both species, commonly sold for live bait in the Southern California area, are indigenous to coastal marine waters locally and have the characteristic of being able to survive but not reproduce in fresh water. The presence of carp in a water supply impoundment is not desirable. Recently, an eradication project using rotenone was undertaken in one of the City reservoirs where an abundance of carp was causing poor water quality (Hoffman and Payette, 1956). In the past, efforts were made to establish several species of trout *(Salmo spp.)*, silver salmon *(Oncorhynchus kisutch)*, and smallmouth bass *(Micropterus dolomieu)* in the City lakes, but without success. Throughout the history of local sportfishing from 1929 through the present time, Water Department personnel have maintained an accurate creel check at each recreation station.

Some reservoirs remain open to fishing throughout the week if patronage warrants. Other reservoirs, less productive or located farther from the City, are open to fishing three days a week; Wednesday, Saturday, and Sunday. Public use mainly determines the length of time any reservoir remains open to the public during each year. Fishing usually extends from early spring through Labor Day, but some of the more popular recreation stations may operate throughout the year. This flexible schedule creates no legal problem because the State of California permits year-round fishing for warm water species.

The number of fishermen using the reservoirs varies with the quality of fishing and the number of reservoirs open to fishing. In 1946, for example, more than 105,000 fishing permits were dispensed to adults at four recreation stations. These anglers caught an estimated 456,000 fish for an average catch of 4.5 fish per trip. However, the average annual catch for all City lakes is about 150,000 fish.

Average angler yield for all reservoirs has been almost 50 pounds per acre for the period of record (1929 to 1957). The annual average of catch per angler day for this period has varied from 2.2 to almost 33 fish and has averaged 6.2 fish for all stations. Records tabulated on a monthly summary basis have shown average catches of almost 9 largemouth bass per angler day for certain reservoirs. Fluctuations and trends in yield have been recorded in Water Department catch records. A preliminary analysis has demonstrated that a close relationship exists between total angler catch and water storage. Each reservoir in the system consistently has a somewhat different type of fishery. One is renowned for crappie fishing, while another offers a productive bass fishery, and yet another is noted for an abundance of large bluegill. The Water Department is now studying the relationship of water chemistry, water level fluctuations, and total storage to fish production. It is anticipated that such information will lead to improved management of the sport fishery.

ADMINISTRATION AND POLICY

The Director of the San Diego Water Department, who is accountable to the City Manager, assigns the administration of the program to the Production Division, whose Superintendent maintains a recreation staff along with the regular operation of dams, reservoirs, and filtration plants. The program receives guidance provided by the City Lakes Recreation Commission. This seven man advisory group is appointed by the City Manager and is made up of leading local citizens. Their function is review of policy, management, and any proposed modification of management which might affect future multiple use of the reservoirs.

MANAGEMENT AND OPERATIONS

Each non-terminal reservoir is normally staffed by a Recreation Keeper, an Assistant Keeper, and two laborers. In addition, at terminal reservoirs there is a full time Reservoir Patrolman who moves about the recreational area strictly enforcing the regulations. During a portion of the recreation season and when the station is closed to the public, some of these men devote their time to normal Water Department duties. These duties are closely integrated with the time required for the recreation program without prejudice to either responsibility. Each Keeper and his assistant are on call 24 hours a day both for recreation and impoundment work. Three District Foremen, one per watershed system, and the Recreation Supervisor complete the Production Superintendent's staff for reservoir recreation.

Station facilities are designed for the convenience and safety of patrons and for the maintenance of Health Department standards. Access to the shoreline is provided wherever possible by maintained roads. Adequate parking areas are available to prevent traffic congestion. The City rents up to 375 rowboats at the various reservoirs. The number of boats available per station each year, however, is allocated on the basis of reservoir size and the anticipated number of bank and boat anglers. Floats, measuring 200 feet by 10 feet and designed to accommodate anglers only, are available at most stations. They have proven to be particularly popular with bluegill and crappie anglers and offer a number of safety features not normally found in such structures. Boats are usually cleaned after each use by hydraulically operated washing devices, and wash water is pumped into evaporation tanks located away from the reservoir and public access.

Portable toilets, either can or pump-out chemical types, are provided every 1000 feet along the shoreline. The most desirable pump-out toilets are popular with the fishermen and are easier to service than the can type. A pumper truck is used to remove sewage material from pump-out toilets, and the waste is hauled to a nearby municipal sewage disposal system. When can toilets are used, the wastes are hauled to a screened burning pit located away from public travel. There, along with garbage and trash wastes, all material is saturated with oil and burned daily. Trash cans are conveniently located throughout station areas. Showers and flush toilets are available in high-use areas where they do not interfere with public health requirements. Fish cleaning facilities are usually provided to discourage use of the shoreline for such purposes. An ample supply of potable drinking water is supplied at strategic locations in all recreation areas, and, when necessary, the supply is filtered, chlorinated, and tested periodically for contamination. All picnic and camping areas have tables, cookstoves, and toilets. Floating facilities, concession buildings, and sanitary units are designed as portable structures so that adjustments with respect to fluctuating water levels can be readily made.

At each recreation station there is a concessionaire, chosen by competitive bidding, who is responsible for issuing all permits and collecting fees. He may also rent outboard motors and tackle, and sell bait, lunches, and soft drinks.

A strict set of rules and regulations governing general conduct, sanitation, boating safety, and the limited use of outboard motors, is enforced by station personnel. The authority for their application is provided in the Municipal Code, City of San Diego. Violation normally results in a stern reprimand or the issuance of a citation of warning. If apprehended in violation of a sanitary regulation, the offender is without hesitation cited to appear in the

Municipal Court of the San Diego Judicial District. Swimming, failure to make use of toilet facilities, throwing food or fish scraps or other material into the water, and trespassing into restricted water areas are prohibited to protect public health. Certain requirements such as prohibition of wading, even with the use of hip boots and waders, are based upon the aesthetics of this form of multiple use. A closed area of water, known as the "deadline distance," is adjacent to the outlet tower at all terminal reservoirs. It is established as an added safeguard for the protection of public health, and keeping people out of such areas is a primary responsibility of the Reservoir Patrolman. The deadline distance is determined from a formula which includes such factors as draft, volume, and other variables.

Although the reservoir recreation program is expensive to maintain, it is the policy of the Water Department that the municipal water consumer shall not bear any of the associated costs. The program, to be self-sustaining over a period of time, operates under a permit system. Fees are set to meet the financial requirements of maintenance and operations, and any profit is used for additional capital outlay expenditures where needed. Individual permit fees per day are as follows: fishing (16 years of age or older) $1.00; boat rental $2.00 per day and $1.50 per half day (approved private boats are permitted but subject to these boat fees); camping $1.00; and duck blind $2.00. Picnicking is free. The average annual expenditure for reservoir recreation for the years from 1945 to 1954 was about $110,000 and has varied from $58,000 to $120,000. During this nine year period, revenue from permit sales has exceeded expenditures by an average of $2,323 per year. Occasionally, however, there are deficits, the highest for any one year being $38,000.

COORDINATION

The California Department of Public Health, acting through the County agency, makes periodic inspections of the operating stations. Special attention is given to all sanitation equipment, enforcement of rules and regulations pertaining to public use, general cleanliness, and station upkeep. The water supply is tested. All operational procedures are reviewed by the County Health Officer, and any change in station management, procedures, or equipment must meet with his approval. Under this program no single instance of water-borne infection has been traced to the municipal water supply.

The management of the fish populations in the City lakes, by law, is vested in the California Department of Fish and Game. The Water Department necessarily manages the anglers' activities. Therefore, it is essential for both agencies to integrate closely all planning and activities connected with fishing. This is accomplished by means of a Working Agreement, a document which defines and allocates responsibilities and sets forth the general investigative and fish management programs for the City lakes. Under this agreement, Department of Fish and Game biologists are currently engaged in several management and research projects on the City reservoirs. Investigative work on the reservoirs at the research level is also being done by fishery research personnel at San Diego State College.

One study by a State College biologist is currently being made to determine the effects of copper sulfate on fish and fishing. In May, 1957, the San Diego City Council contracted with San Diego State College for a study of the spawning of largemouth bass in one of the problem reservoirs. Basically, these studies are designed to implement the fishery management program at the San Diego reservoirs.

All recreation stations are located in high fire hazard areas of the County. Full cooperation is extended both to the U. S. Forest Service and State Division of Forestry in adhering to required fire protection standards and in enforcing preventive measures. All cooking stoves at campgrounds and picnic areas are inspected by forestry officials.

The Water Department maintains an active public relations program with the local press and sportsmen's organizations. A weekly fishing report giving general catch data and fishing news is distributed to over a hundred sporting goods dealers, sportsmen's organizations, and interested individuals. Reservoir problems that affect fishing are given immediate attention by Water Department personnel, and information as to remedial measures taken is supplied promptly to the public. Staff members of the Production Division attend most organized sportsmen's meetings in San Diego County. Their attendance affords an excellent opportunity to keep the groups well informed on the general fishery program, the present status of operations, and future planning.

FUTURE PLANNING

With availability of impounded water being such a variable, it becomes difficult to plan ahead from year to year with any degree of confidence. However, steps are now being taken to reactivate an obsolete recreation station with modern facilities and equipment. The capital outlay cost of this project is set at $65,000, but the actual expenditure before the opening day is apt to be considerably more. Future planning includes use of a smaller impoundment for the culture of largemouth bass fingerlings. These young bass will be stocked primarily in City reservoirs and in other San Diego County waters where the needs arise.

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SURVIVAL THROUGH HATCHING OF EGGS FROM SILVER SALMON *(ONCORHYNCHUS KISUTCH)*[1]

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ABSTRACT

During the 1953-54 migration season 63 female silver salmon *(Oncorhynchus kisutch)* of the 1950 brood year were recovered in the traps at the University of Washington. Eggs from each female were fertilized by one male only and the eggs maintained as separate lots through hatching. Hatching was completed in most lots from 40 to 43 days after fertilization in water of about 52.5°F. The mortality of eggs was studied during three stages of development. Mortality appeared to be related more to the female than the male parent. Females arriving during the first portion of the run produced eggs that had higher survival than females arriving during the last portion of the run. Survival through hatching was 48 percent for about 198,000 eggs produced by the 63 females. This survival was considerably less than survival rates reported in the literature. A delayed entry into the ponds was associated with increased water temperature. Over-retention of the eggs may have caused the below-normal survival.

INTRODUCTION

During the fall of 1953 and winter of 1954, 151 silver salmon *(Oncorhynchus kisutch)* were taken in the hatchery trap operated by the School of Fisheries at the University of Washington.[2] Of these, 116 were marked fish of the 1950 brood year[3] which had been released at the University of Washington in 1952 (Donaldson and Allen, 1958). The eggs from each female were fertilized by a single male and then maintained as separate lots at least through completion of hatching. Consequently it was possible to study the variation in survival of eggs from individual females with progression of the run.

HATCHERY PROCEDURE

The fishway, holding ponds, and traps at the University of Washington are described in Donaldson and Allen *(loc. cit.)*. Each day the silver salmon taken in the traps were killed, spawned, or placed in holding pens. Fish in holding pens were identified by a numbered tag.

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[1] Contribution No. 38, University of Washington School of Fisheries.
[2] Allen, G. H. 1956 Migration, distribution, and movement of Puget Sound silver Salmon. Thesis. University of Washington, Seattle.
[3] The brood year is dated from the fall of the year of migration to the spawning grounds. Silver salmon mature mainly at three years. Thus silver salmon returning in the fall of 1953 and winter of 1954 give rise to the 1953 brood year, and are members of the 1950 brood year.

The eggs from each female were fertilized by one male only and comprise a single lot. Lots were numbered consecutively in order of spawning. The selection of the male was based primarily on length and general robust physical appearance. Because of the extended time of the run and the limited holding capacity of the ponds, the male could be selected only from those present at the time of spawning the female. Consequently only 26 males were used for fertilizing the eggs of 63 females. The number of males which fertilized 1, 2, 3, 4, 5, and 6 lots of eggs was 11, 3, 3, 1, 3, and 3 respectively.

Decision to take eggs from a female was determined by inspection for looseness of the eggs in the body cavity, development of the urogenital papillae, and by the ease with which eggs could be stripped from the fish. Eggs were taken in an enamel pan tempered to the temperature of the water in the ponds. Sperm was added to the dry eggs and then eggs and sperm mixed thoroughly. The eggs were water-hardened by placing them on wire-screen incubating trays floated in hatchery troughs supplied with water from Lake Union (lake water). After hardening the eggs were slowly acclimatized to well water, and transferred to a drip-type incubator supplied with the well water.

All dead eggs were removed before the eggs were placed in the incubator (initial pick). The eggs were retained in the incubator until the eye pigment of the embryos were visible through the shell of the egg (eyed eggs) and were then subjected to physical shock (bumping) by siphoning the eggs from the trays through a rubber hose into a rubber pail. Such physical shock caused precipitation of the protein in those eggs where development had not taken place. Dead eggs were removed after shock treatment (bump pickoff). Egg lots were left untouched until the eyed-egg stage except for those lots where heavy egg mortality was evident, in which case the trays were taken from the incubator and dead eggs removed. Two to seven days before the expected date of hatching, depending upon availability of hatchery space, the eggs were removed from the incubator and placed in hatching baskets set in individual fry-tight compartments that were fitted 6 to a 15-foot Williamson-type hatchery trough. Dead eggs were then removed several times a week.

Estimates of the number of eggs were made at the time of the bumping using the Von-Bayer volume displacement method of egg enumeration. The number of eggs in each lot ranged from approximately 1,400 to 5,700.[2]

The survival through hatching for each lot is a percentage calculated as follows:

$$\frac{\text{(total estimated eggs per lot)} - \text{(total recorded egg mortality)}}{\text{(total estimated eggs per lot)}} \times 100$$

This figure also represents the percentage of fry produced by each lot of eggs. Mortality through hatching (100 minus the percentage survival through hatching) was divided into three parts: initial pick, pre-eyed eggs, and eyed eggs. The eyed-egg stage occurs approximately half way between dates of fertilization and hatching. Date of bumping each lot of eyed eggs was taken as the separation point between eyed-egg and non-eyed egg stages and mortality of eyed eggs refers to losses from immediately after the bump-pickoff through hatching. Mortality as pre-eyed eggs refer to mortality from the day after fertilization up to and including the day of the bump pickoff. Mortality of non-eyed eggs is the sum of the mortality on the day of spawning (initial pick) and mortality of pre-eyed eggs.

DESCRIPTION OF SILVER SALMON RUN DURING 1953-54 MIGRATORY SEASON

Because the results of this study have to be interpreted in terms of the nature of the silver salmon run to the University of Washington from which the eggs were obtained, the more important features of this run are described.

The 1953 run was of 32 two-year-old fish (jacks) of the 1951 brood year and 119 three-year-old fish of the 1950 brood year. Of the latter, 3 were unmarked fish and 116 marked fish released at the University of Washington in 1952 (Donaldson and Allen, *loc. cit.)*. Date of return of marked, 1950 brood-year silver salmon to the hatchery ponds during the period November 18 to January 31 is shown in Figure 1. Three un-

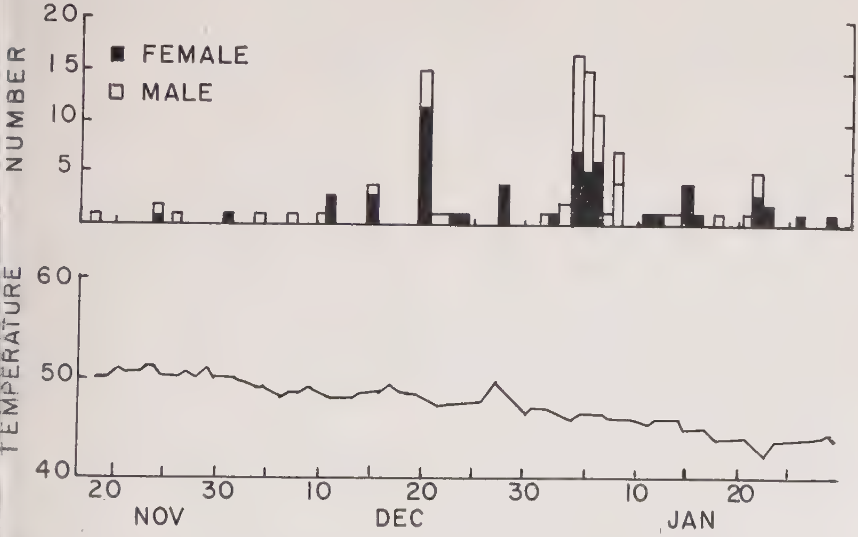

FIGURE 1.—Daily return of male and female silver salmon of the 1950 brood year to the University of Washington during the 1953-54 migration season, and daily temperature in F° of water issuing from the fishway.

marked fish, and three marked fish returning on February 25 are not included. The jacks arrived mainly during the earlier portion of the run. The major portion of the run did not appear until December 20. This was in contrast to companion groups of 1950 brood-year silver salmon which appeared during October and November at hatcheries on Issaquah, and Minter Creeks, Puget Sound, Washington.

The length of life of 22 male three-year-old silver salmon which died from "natural" causes after being placed into the holding ponds ranged from 0 to 22 days. Three fish lived 12 days and five fish lived 14 days after entering the ponds. Over half (13) of the 22 fish lived from 12 to 16 days after entry into the ponds. Willis (1954) studying silver salmon in Spring Creek, tributary to Wilson Creek, Tillamook Bay, Oregon found by tagging that the average length of time spent in the creek until death was about 11 days for females and 12 days for males over 20 inches (length used to separate three-year-old fish from jacks).

The majority of the female silver salmon were ready to spawn on entering the hatchery trap. Of the 65 females handled during the run, 52 were spawned on the day of their arrival, and 8 were retained for an average of 4.6 days before spawning. Not included were three lots from dead females which had jumped out of the fishway; one lot from a female spawned prematurely; and one lot donated to another study. Of the eight fish which were not ripe on arrival, four entered the ponds prior to December 15 and four arrived on December 20. These females, therefore, belonged to the "early" portion of the run. All females arriving after December 20 were ripe on arrival, with the exception of one female with very immature eggs which was spawned prematurely on January 5.

Rate of Development of Eggs

During the first portion of the run eggs were incubated and hatched in well water only. During the latter portion of the run, lots were incubated in well water but hatched in a combination of well and lake water. This was necessary as other experiments in the hatchery caused a heavy demand on the limited well water supply. Temperature of the well water was recorded daily from thermometers located inside the hatchery. Temperature of the lake water was recorded daily from a dial-type thermometer installed in an outside rearing pond. This pond was supplied with lake water from the same source as that utilized in the hatchery. These temperature data are summarized in Table 1.

Most lots incubated and hatched in well water began hatching 34 to 38 days after ferilization. Hatching continued from two to seven days, and was completed in most lots from 40 to 43 days after fertilization (Table 2). The well water deviated little from a mean temperature of 52.5F° during incubation and hatching. At this temperature eggs hatched in an average of 41.5 days after fertilization, and required an average of 850 temper-

TABLE 1.—*Temperatures in F° of outside ponds, inside well water, and mixture of well and lake water inside hatchery at the University of Washington hatchery in 1953-54,*

Period	Well water		Lake water		Mixture of well and lake water	
	Mean	Range	Mean	Range	Mean	Range
December	53.1	52.5–54.5	48.5	46.0–50.0		
January 1–20	52.0	51.5–52.5	45.3	42.5–48.0		
January 21–31					47.9	47.5–48.5
February			46.5	44.0–49.5	48.1	47.5–49.5
March 1-15			47.3	46.0–49.0	48.2	48.0–49.0

TABLE 2.—*Variation in number of days from fertilization of silver salmon eggs until first hatching; days required for hatching; and days from fertilization until hatching was completed.*

Days from time of fertilization	Number of egg lots			Days required for hatching	Number of egg lots	
	Until hatching started	Until hatching completed				
	Eggs in well water	Eggs in well water	Eggs in mixture well and lake water		Eggs in well water	Eggs in mixture well and lake water
31	1			1	0	
32	1			2	1	
33	0			3	8	
34	6			4	4	
35	13			5	10	
36	6			6	8	
37	8			7	5	
38	7	1		8	1	1
39	1	1		9	0	1
40	2	7		10	0	0
41		16		11	1	2
42		10		12		2
43		6	1	13		1
44		0	0	14		1
45		1	1			
46			4			
47			0			
48			2			
Totals	45	42	8		38	8

ature units (Wallich, 1900) to complete hatching. This is over 100 units greater than for the few other comparable hatching experiments reported in the literature (Table 3).

TABLE 3.—*Compilation of data on survival through hatching of eggs from silver salmon.*

Source of data	Shaw and Maga (1940)	Shapovalov and Berrian (1940)	Carl (1940)	Salo and Noble[1]	Present study
Number of eggs	13,600	7,500	4,000	450,000	198,000
Percent survival through hatching	80	66	86	87	48
Mean temperature	51.3	48.0			52.5
Temperature units required through hatching	733	772			850
Days from fertilization until maximum hatching	37	48			41.5
Days required for hatching	3	10			2–11

[1] Personal communication.

SURVIVAL AND MORTALITY THROUGH HATCHING

History of mortality of eggs from 63 individual females is presented graphically in Figure 2. In Figure 2, the bars depict mortality and the unoccupied areas below the 100 percent level represent survival through hatching. The date of spawning of the female producing each lot is also indicated.

The total number of eggs taken into the hatchery from the 63 females was approximately 198,000 eggs. Mortality of non-eyed eggs was 34 percent and of eyed eggs 18 percent. Survival through hatching (fry produced) was 48 percent.

A close relationship existed between mortalities recorded at spawning (initial pick) and mortality through hatching (Figure 2). Excluding 3 lots (numbers 51, 52, and 56) whose mortalities were related directly to poor quality of sperm, and lot 9 which suffered mortalities from a water failure, a coefficient of correlation (r) between percent mortality at spawning and percent mortality through hatching for 59 lots was 0.62 (1 percent level of significance 0.35). Of 47 lots with less than 5.0 percent initial pick only three suffered 100 percent mortality, and these lots were from females

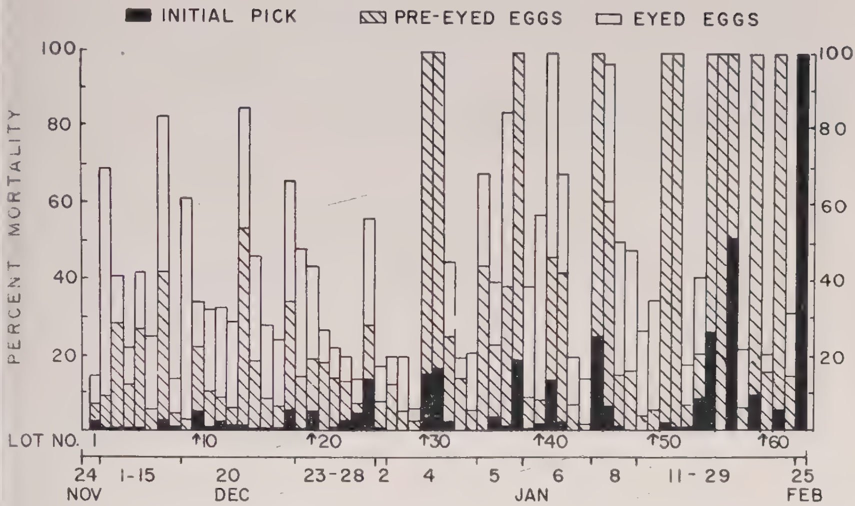

FIGURE 2.—Percent mortality and survival of 63 lots of silver salmon eggs during three stages of development from fertilization through hatching. [*Lots No. 20, 27, 28, and 45 recovered from dead females which jumped from fishway. Lot No. 9 suffered mortality from a water supply failure just prior to hatching. Lot No. 55 eggs were water-hardened in the female before spawning*].

arriving late in the run. Of 17 lots with 5.0 percent or greater initial pick, 10 eventually suffered 100 percent mortality, one had a mortality of 97 percent, and 6 ranged between 14 and 66 percent mortality. Five of the latter six lots were from females arriving early in the run.

As some of the larger more robust males were retained in the ponds to fertilize eggs from females arriving at different times in the run, it was possible to study percent survival of lots as related to the number of days the male parent was retained in the holding pond prior to fertilization (Table 4). This study of the effect of over-retention of the male in producing poor sperm was limited by the large number of lots which had an initial pick of greater than 5.0 percent, and therefore involved eggs which were initially poor. Such an occurrence could not be predicted nor prevented. Thus of the 14 lots suffering 100 percent mortality (lot number 46 with 97 percent mortality included), mortality caused through over-retention of the male was indicated for three lots and mortality to poor eggs for 11 lots (Table 5).

The effect of successive spawning of the same male was shown by the percent survival through hatching of lots resulting from seven males fertilizing two or more lots during the same day (Table 6). There was no indication that repeated use of the same male resulted in decreased survival of the eggs.

Analysis of the most probable cause of mortality of eggs was compromised by the large number of factors which may affect mortality and survival, and by the fact that the experiment was not specifically designed to study this question. However, the analysis indicated mortality was related more to the female than to the male parent (Table 7). This could

TABLE 4.—*Number of lots of silver salmon eggs with poor survival compared with number of days male parents was in holding pond prior to fertilization of eggs.*

Percent mortality through hatching of eggs	Number of days male parent held in pond prior to fertilization of eggs		Totals
	0–7	9–18	
Greater than 95	6 lots	8 lots	14 lots
Less than 85	47 lots	2 lots	49 lots
Totals	53 lots	10 lots	63 lots

TABLE 5.—*Comparison of mortality of silver salmon eggs at spawning [for 14 lots suffering 100 percent mortality through hatching] to the number of days male parent was held in pond before fertilization of the egg lot.*

Days male parent held in ponds before fertilization of egg lot	Egg mortality at spawning (initial pick)		
		Greater than 5 percent	Less than 5 percent
0–7	Total	6 lots	0 lots
	Lot No.	31, 38, 41, 45, 46, 63	
9–18	Total	5 lots	3 lots
	Lot No.	30, 55, 57, 59, 61	51, 52, 56

TABLE 6.—*Percent survival through hatching of egg lots of silver salmon fertilized in succession by the same male on the same day.*

Male No.	Date of arrival	Percent survival of successive lots			
		1	2	3	4
1	Dec. 10	59	58		
2	Dec. 20	17	86	39	
3	Dec. 20	71	15	54	72
4	Dec. 20	66	68	67	
5	Dec. 28	80	86	44	
6	Jan. 1	80	80		
7	Jan. 5	61	16		

TABLE 7.—*Most probable causes of mortality through hatching of eggs from 63 female silver salmon.*

Lots with 100 percent mortality	
Related to female	10 lots
Related to male	3 lots
Lots with less than 100 percent mortality	
Could not be related to either parent	48 lots
Lots suffering mortality from mechanical failures, etc.	2 lots
Total	63 lots

have resulted from selecting and retaining only the most robust appearing males while using all females.

CHANGE IN MORTALITY AND SURVIVAL DURING RUN

The individual handling of eggs from each female was employed to measure variation in survival of egg lots in order to select the best lots for selective breeding. As previously stated no experimental techniques were employed to study specific causes of mortality. However, a cursory glance at Figure 2 reveals that whatever the cause, there were a greater number of lots with poor survival during the last part of the run.

Percent survival through hatching of lots was compared with length of parents, and to time of arrival of parents. Both large and small male parents produced lots with high and low survivals. There was a slight trend for smaller females to produce lots with higher survivals. Of thirteen females which were 57 centimeters or less in fork length, two produced lots with survivals of 40 and 60 percent, and eleven with survivals above 70 percent. However, there was no tendency for the smaller fish to arrive earlier in the run than larger fish. Larger fish (58 centimeters fork length or greater) spent part of their salt water life in the Pacific ocean, while smaller fish (57 centimeters or less) spent their salt water life within Puget Sound or closely adjoining regions.[2]

The percent survival of lots from small and large fish arriving during three different parts of the run are presented in Table 8. A distinct increase in the number of poor lots occurred in the late portion of the run. The affect was only shown for the larger females.

SIGNIFICANCE TO SALMON MANAGEMENT

Although there is extensive artificial propagation of silver salmon by fisheries agencies in the United States, there has been little published data on the natural variations in hatching and development of eggs of the species. Comparable data on the survival to hatching of silver salmon eggs are mainly limited to records of control lots of eggs used in experiments involving the hatching of eggs (Table 3). Shapovalov and Taft (1954) state that under normal hatchery conditions the hatch is between 80 and 90 per cent of the eggs taken. The 1950 brood-year silver salmon returning to Minter Creek, Washington in 1953 (Salo, 1958), produced eggs which had survival through hatching of 87 percent[4]. Thus it would appear reasonable to consider the survival through hatching of 48 percent of the eggs from the 1950 brood year at the University of Washington to be much less than normal under average conditions.

The importance of temperature of the water in influencing the biology of fishes is generally recognized. Chambers *et. al.* (1954)[5] showed that in the State of Washington sockeye salmon *(Oncorhynchus nerka)* and chinook salmon. *(O. tschawytscha)* spawned primarily within a temperature range of 48-52°F. and that silver salmon spawned generally at a lower temperature range of 40-48°F. Royal (1953) indicated that the time of appearance on the spawning grounds in stocks ("races") of sockeye salmon in the Fraser River was of major importance in obtaining optimum results from spawning. Peak of spawning for the Fraser River sockeye takes place at 50°F., and that delays in spawning from high water temperatures results in decreased survival of eggs.

Only water from Lake Union (lake water) was used at the University of Washington during the 1951-52 and 1952-53 migration periods. In 1953-54 season, the well water of uniform temperature was added to the hatchery supply. This water tended to raise the cold lake-water temperatures of fall and winter. The daily temperature of the hatchery water during the three migration periods is compared with the time of entry of silver salmon into the hatchery ponds (Figure 3). The delay in time of entry of the 1950 brood-year silver salmon was correlated with the change in water temperature issuing from the fishway. In each year, the peak of movement into the ponds did not occur until the water temperature had reached to below 50°F. Water temperatures had dropped to below 50°F. by late November and early December at the Minter Creek and Issaquah hatcheries respectively to which other groups of 1950 brood-year silver salmon had migrated by this time.[2]

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[4] Salo, E. O., and R. E. Noble. Personal communication. 1958

[5] Chambers, J. M., R. T. Pressey, J. R. Donaldson, W. R. McKinley, 1954. Research relating to study on spawning grounds in natural area. State of Washington, Department of Fisheries. Annual Report to U. S. Army Corps of Engineers. Unpublished.

TABLE 8.—*Percent survival through hatching of 57 lots of silver salmon eggs from females arriving during three periods of the run*[1].

Period of run	Percent survival through hatching	Fork length in centimeters of female parent		
		<57 or less	>58 or more	Combined
Prior to Dec. 30	>75	2 lots	5 lots	7 lots
	50–75	2	9	11
	5–50	2	3	5
	<5	0 (0)[1]	0 (0)	0 (0)
Jan. 1–10	>75	3 lots	4 lots	7 lots
	50–75	1	6	7
	5–50	0	4	4
	<5	1 (20)	3 (18)	4 (22)
After Jan. 10	>75	1 lot	3 lots	4 lots
	50–75	0	3	3
	5–50	0	0	0
	<5	0 (0)	5 (45)	5 (42)

[1] Numbers in parentheses within each group are the percentages, of the total number of lots, which had survival of less than 5 percent.

The 1950 brood year at the University of Washington was from a run of silver salmon at the Green River (Soos Creek) hatchery (Donaldson and Allen, *loc. cit.)*. This run generally appears at the hatchery racks during late November and is spawned during the first two weeks in December. In the 1953-54 run to the University of Washington, the only females which were not ripe on arrival appeared in the ponds on or prior to December 20. The survival of eggs from females arriving later in the run was less than eggs from early-arriving females. Thus all the evidence indicated that the below average survival of eggs from the 1950 brood year silver salmon at the University of Washington was related to the delay in entry of the run into the ponds.

There was no way to ascertain which of several specific factors caused the increased mortality. Over-retention of the eggs in the females coupled with incubation in water temperatures which may be slightly higher than optimum for the species is the most apparent contributing factor. Regardless of specific causes it would appear that the biological principles presented by Royal *(loc. cit.)* which are the basis for regulating the Fraser River sockeye fishery have been demonstrated for the silver salmon in this particular case.

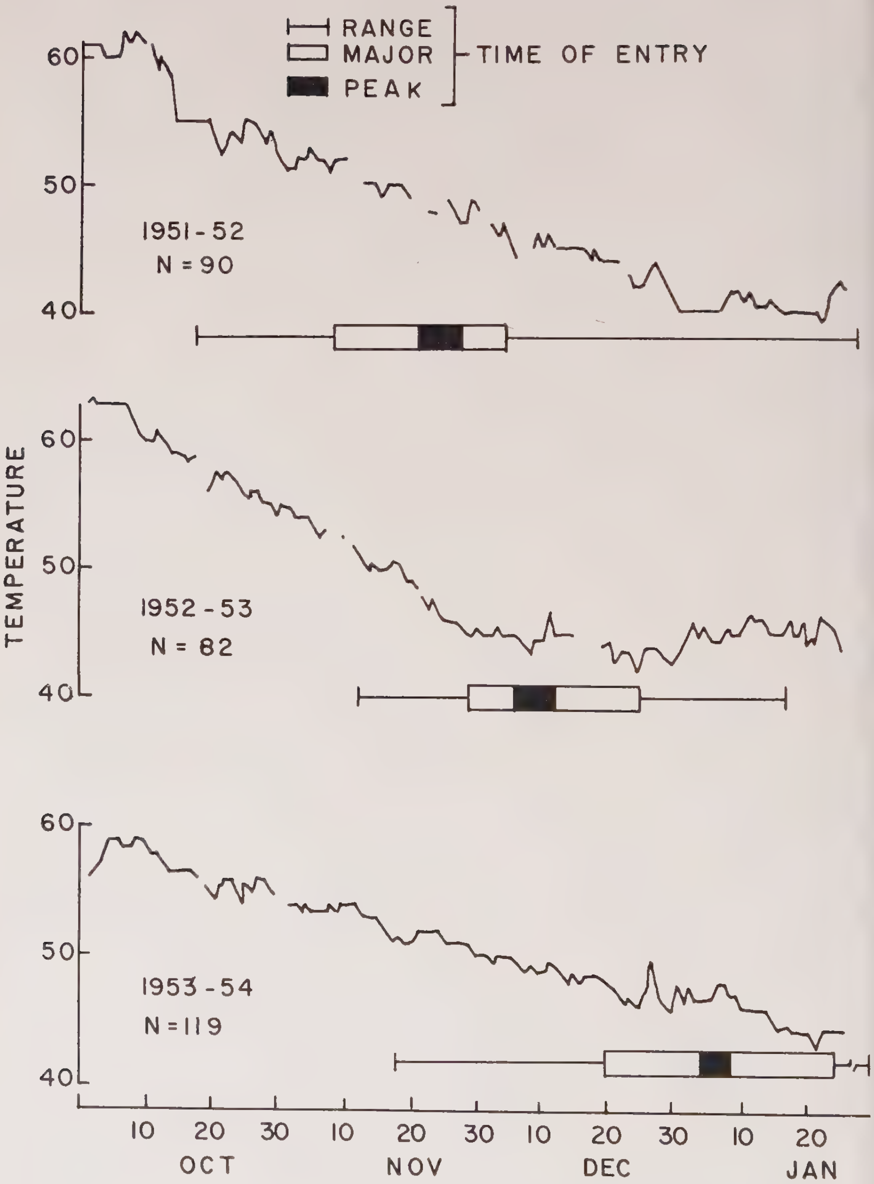

FIGURE 3.—Comparison of time of entry of three-year-old silver salmon into hatchery traps at the University of Washington with temperature of water in F° during three migratory season. [*The 1951-52 migratory season was the first year of operation of the fishway and hatchery traps*].

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the University of Washington School of Fisheries for the opportunity to study the 1953-54 run of salmon to the university ponds. The State of Washington Department of Fisheries supplied the stock of silver salmon.

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THE SURVIVAL OF FIN-CLIPPED AND LATEX-INJECTED REDEAR SUNFISH[1]

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Abstract

Redear sunfish *(Lepomis microlophus)* were marked by latex injection and by fin-clipping in Wyland Lake, Indiana, to determine immediate and delayed effects of these techniques on survival. A variety of fin-clips were used and latex was injected subdermally with a hypodermic syringe in the occiput region and posterior dorsal region. From recaptures made during the year of marking and in the next year the following conclusions were drawn. (1) Survival of fin-clipped fish below and above 123 millimeters fork length was similar two weeks following marking and proportionate recaptures from these two size groups were also made a year subsequent to marking for fish carrying either a single fin-clip or a double fin-clip. (2) There was no immediate mortality from subdermal injection of latex; and survival of fish of different sizes was the same with no difference noted between the two sites of injection. (3) Survival of fish marked with posterior-dorsal latex injections was similar to that of fin-clipped fish over a year period, but fish marked with occiput injections were recaptured at a lower rate than those of the other groups. There is some evidence that the occiput injection is sloughed off. The spot may heal or it may become infected and the fish die. In either event the mark is lost. (4) Latex marking does not possess an advantage over fin-clipping from the point of view of survival. The new technique does offer an increased variety of marks, however; but careful choice of the injection site must be made, since all sites are not equally favorable.

Introduction

Fin-clipping, removal of a portion of the maxillary bone, and the attachment of a great variety of tags are used to mark fish for future identification. These methods are quite adequate for certain types of studies. For precise work on survival and abundance, however, there is a possibility that mutilation or the attachment of a foreign object may cause increased mortality or altered behavior. Either of these effects would bias population measurements which depend upon mark-and-recapture techniques. A non-mutilation mark would be preferred if it could be applied to large groups of fish. At least, it could be used to test the suitability of the methods now in use. The present work represents a test of the survival of the subdermal latex injection mark developed by Davis (1955) with that of fin-clipping.

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The search for a non-mutilation technique has centered around various methods of tattooing and hypodermic subdermal injection. Hickling (1945) tattooed plaice with india ink and reported that the mark was indentifiable for about seven weeks. Gerking (1953) used a similar mark on a variety of species, including centrarchids, but it could be recognized for only three weeks. Chapman (1957) reported that a tattooed mark of a mixture of titanium dioxide and india ink lasted for a maximum period of five months on juvenile steelhead trout *(Salmo gairdneri)*. Trypan blue mixed with TiO_2 was also used, but the duration of the mark was not reported. The inert pigments, aluminum oxide, ferric oxide and chrome green, have been tattooed on juvenile chinook salmon *(Oncorhynchus tshawytscha)* with good results for short-time experiments (Dustan and Bostick 1956).

Another group of workers have attempted to inject various substances beneath the skin with a hypodermic syringe. Dunn and Coker (1951) used 14 biological stains but none of them was entirely successful in leaving a discrete, recognizable spot. Trypan blue, the most satisfactory stain, had a tendency to spread away from the injection site. Wigley's (1952) experiments were more promising. He injected cadmium sulfide, mercuric sulfide and carbon black under the skin of lampreys, and the marks did not fade over a period of 18 months.

Davis's technique deserves further investigation, however, because of the possibility of using a variety of colors and various sites of injection. Recently, a successful injection of latex between the ventral fins of steelhead trout has been reported (Chapman, 1957) in addition to the occiput region which Davis used. Chapman observed his fish for a period of ten weeks and Davis for six months. Certain kinds of experiments require a longer period. Consequently, the present work was undertaken to learn whether or not the subdermal latex injection mark could be used for quantitative measurements which require that fish be marked for at least a year.

Our experiment compared the survival of fish marked with latex in the occiput and in the posterior dorsal region with that of a fin-clipped group. Fin-clipping was chosen as the least objectionable type of mutilation because Ricker (1946, 1949) found in pond expirements and in lakes that it does not appreciably affect survival among bluegills *(Lepomis macrochirus)* and redear sunfish *(Lepomis microlophus)* of moderate size. Both species were included in our experiments but only the redear sunfish results are reported here. Recaptures of the redear were more numerous and the conclusions were more convincing as a consequence. The outcome of the bluegill marking was essentially the same as for the redear, however.

The experiment was conducted in Wyland Lake, Kosciusko County, Indiana, located four miles southeast of Winona Lake. The lake is 3.31 hectares (8.2 acres) in extent with a maximum depth of 6 meters (19.7 feet). The fish populations of the lake were studied in 1955 and 1956.

PROCEDURE

TRAPPING

Wire traps were used exclusively for capturing the fish. The traps varied from three and one-half to four feet long with a diameter of approximately two and one-half feet. The majority were made of one-inch mesh chicken wire reinforced with heavy gauge wire at each end and in the middle. The other traps were made of heavy gauge hardware cloth with a mesh of ¾ inch. Each was equipped with a single funnel. The hardware cloth traps caught smaller individuals than those made of chicken wire, but otherwise there did not appear to be any difference in the effectiveness of the two types.

Ten traps were used each year. They were scattered around the shore line of the lake, and as trapping progressed, they were moved from place to place in order to secure a random sample of the population. Typically, the fish were processed as each trap was lifted, and they were released in the same general location.

FIN-CLIPPING

The fins were clipped close to the body with straight-edged bone forceps. As a general rule, a spot of blood appeared at the surface of the cut after the pectoral fins were removed. Usually, the removal of the ventral fins did not cause bleeding.

In our experience, there is little or no regeneration of the fins if they are clipped in this fashion. If regeneration does occur, the fin is small and distorted in comparison with a normal fin, and the disfigurement can be easily recognized.

LATEX INJECTION

A five ml. capacity Becton-Dickinson veterinary syringe with a Luer Lok adapter was used. This syringe is constructed of stainless steel with heavy glass sides. The plunger is rubber-tipped and the rubber-glass contact prevented the syringe from jamming with the injection fluid. The syringe was fitted with a 20-gauge, regular-point, one-inch hypodermic needle.

The injection fluid was "Latex Injection Compound" supplied by General Biological Supply House, Inc. It can be obtained in a variety of colors. We have used yellow, red, and white. The white latex was compounded by special request. The injection compound was diluted to twice its original volume with water before use. The latex is dissolved in an ammonia solution which is the normal excretory product of fishes. About 0.2 ml. of the latex solution was used for each mark. This small quantity is not believed to be toxic, but no experiment has been conducted to confirm this opinion.

Two different places on the body were injected which are called "occiput" and "posterior dorsal" sites. The occiput site is located on either the right or left side of the fish in the occiput region. The needle is inserted beneath the dermis and a spot of latex is forced between the dermis and the muscle layer (Davis, 1955). The other injection site was located on either side of the posterior base of the dorsal fin. Here, the latex is forced into a small channel, presumably a lymph channel, which runs the entire length of the fin. The mark appears as a colored streak along the base of the fin, its length depending upon the degree to which the channel is filled.

The fish were anaesthetized with urethan during the early part of marking schedule, but this procedure was abandoned as the research assistants became more experienced.

MARKING SCHEDULE

Exactly 42 days were spent trapping in both 1955 and 1956. Each 42-day interval was composed of three, 14-day periods in which the fish were marked distinctively. A schedule of the 1955 marking is given in Table 1 in which R = right, L = left, P = pectoral, V = ventral, O = occiput, PD = posterior dorsal, Y = yellow, and Re = red. Thus, ROY means "right occiput yellow" or a fish which had been injected in the right occiput with yellow latex; RPRV refers to a fin-clip mark where the right pectoral and right ventral fins were removed. All right side marks specify fish under 123 mm. fork length at the time of capture; left side marks designate a group which were 123 mm. and above.

The marking schedule was established to attempt the measurement of seasonal mortality rates, and the marking experiment was superimposed upon it. The results of the former experiment will be reported at a later time.

TABLE 1. *The 1955 marking schedule for redear sunfish in Wyland Lake, Indiana.* [All right marks (R) refer to fish under 123 mm. fork length; left marks (L) designate fish of 123 mm. or above. See text for explanation of other symbols.]

Date	Type of mark	Description	Number of fish marked
Period I June 8-21	Fin-clip	RP	67
	Fin-clip	LP	87
	Latex	ROY	38
	Latex	LOY	83
Period II June 22 to July 5	Fin-clip	RV	22
	Fin-clip	LV	20
	Latex	RPDY	11
	Latex	LPDY	13
Period III July 6-19	Fin-clip	RPRV	16
	Fin-clip	LPLV	13
	Latex	RORe	15
	Latex	LORe	19

SURVIVAL OF MARKED FISH

The schedule of marking permits comparisons of two general types to be made. First, any immediate differential mortality among the various groups of marked fish should be revealed by the rate of recapture during the year of marking. Second, the 1956 rate of recapture of the fish marked in 1955 should reveal any long term effects of the various types of marks on survival.

Valid comparisons of the various groups of marks depend upon random samples to be drawn from the marked fish at large. The greatest possibility of error in this respect is in the capture of an individual more than once, and redear sunfish are notoriously susceptible to capture in wire traps. This type of error has been minimized by counting the number of recaptures which are taken during a relatively short period of time.

Differential loss of marked fish by immigration, emigration, or fishing would also lead to spurious conclusions. The inlet and outlet of Wyland Lake are very small, and no large aggregations of any species were seen at either location during the two summers of observation. Migrations at other times of year seem unlikely since the ditch into which Wyland Lake drains has a fauna typical of the small streams in the region.

RECAPTURES DURING THE YEAR OF MARKING

The most sensitive test of the immediate effect of marking in 1955 is a comparison of the number of recaptures taken during the two-week period following marking. Thus, the fish marked in Period I and recaptured in Period II could be combined with those marked in Period II and recaptured in Period III for the test. The individuals marked in Period III cannot be included in the comparison since they were not sought until the following year.

A chi-square test of homogeneity was made on the fin-clipped group (Table 2). This test is based on the mean expected survival computed from the marginal totals (Snedecor, 1956, p. 225). Expected numbers for each cell of the table are calculated and compared with those actually observed. All analyses have been made in a similar manner, although the tables which follow have been condensed to save space. The chi-square value of 2.557 with 3 d. f. (P = 0.46) indicates that the variations in recapture rate were no greater than would be expected in random samples from a homogeneous population. No one of the fin-clips possessed an advantage over any other.

TABLE 2. *The survival of fin-clipped redear sunfish two weeks after marking.*

Fin-clip	Recaptures observed	Number unobserved	Total marked
Right pectoral (RP)	14	53	67
Right ventral (RV)	3	19	22
Left pectoral (LP)	19	68	87
Left ventral (LV)	7	13	20
Totals	43	153	196

Chi-square = 2.557 with 3 d. f.; P = 0.46.

Separate tests based on the type of fin removed and the side of the fish om which the fin was taken confirmed this opinion. The rate of recapture pectoral fins was 21.4 percent and that of ventral fins was 23.8 percent hi-square = 0.112 with 1 d. f.; P = 0.72). Right side fin-clips were covered at a rate of 19.1 percent and left side fine-clips at a rate of 24.2 rcent (chi-square = 0.750 with 1 d. f.; P = 0.38).

A similar comparison was made with the latex injection marks (Table 3). ese four marks were also homogeneous with respect to one another (chi-uare = 1.949 with 3 d. f.; P = 0.57). The rate of recovery of posterior rsal marks was similar to the recovery of occiput marks (chi-square = 1.32 th 1 d. f.; P = 0.25) on the basis of our samples. Right and left sides re returned at an equivalent rate when they were compared without regard the site of the injection (chi-square = 0.046 with 1 d. f.; P = 0.85).

TABLE 3. *The survival of latex-injected redear sunfish two weeks after marking.*

Latex mark[1]	Total marked	Recaptures	Percentage Recaptured
Y	38	8	21.0
Y	83	20	24.1
DY	11	2	18.2
DY	13	1	7.7

hi-square = 1.949 with 3 d. f.; P = 0.57.

See text for explanation of abbreviations.

Since both the fin-clip and latex injection groups are each homogeneous ith respect to their rate of recapture, it is possible to pool the recaptures rom each group for a comparison of the survival of the two types of marks Table 4). Of the 196 fish which were fin-clipped, 21.9 percent were obrved during the two-week period following marking, and 21.4 percent of he injection marks were recaptured. Such close agreement indicates a very gh probability that no difference exists between the two groups.

If mortality occurred subsequent to marking, it was the same for both pes of marking techniques. The effect of trapping the fish and handling hem for measuring weight and length may be unfavorable, but we have not

ABLE 4.—*Comparison of the survival of fin-clipped and latex-injected redear sunfish two weeks after marking.*

Mark	Total marked	Recaptures	Percentage recaptured
n-clips	196	43	21.9
tex	145	31	21.4

hi-square = 0.012 with 1 d. f.; P = 0.99.

had an opportunity to test it. Since no immediate differential mortality was detected among the two groups, it is concluded that latex injection and fin-clipping could be used equally well for short-term studies.

RECAPTURES DURING THE YEAR FOLLOWING MARKING

In 1956 the recaptures of fish marked the previous year were given a distinctive mark. This procedure distinguished between individuals which were seen for the first time from individuals captured more than once. Therefore, it was possible to compare the survival of the marked fish on the basis of single recaptures only.

A high percentage of the fish fin-clipped in 1955 was taken during the 42-day period of observation in 1956, the average return for the whole group being 26.5 percent (Table 5). The LV recaptures were returned at a lower rate (17.7 percent) than the RV, RP, and LP groups (av. = 27.8 percent), but the test of homogeneity among the four kinds of marks indicated that such a result might be expected on the basis of sampling (chi-square = 2.053 with 3 d. f.; P = 0.57).

TABLE 5. *The survival of fin-clipped redear sunfish a year following marking.*

Fin-clip	Total marked	Recaptures	Percentage recaptured
Right pectoral (RP)	67	18	26.9
Left pectoral (LP)	87	29	29.9
Right ventral (RV)	22	5	29.4
Left ventral (LV)	20	3	17.7

Chi-square = 2.053 with 3 d. f.; P = 0.57.

The double fin-clipped fish of Period III in 1955 were also captured during the 1956 trapping period, and their survival was compared with the pooled data of the four groups which had only one fin removed. Five of the original group of 29 marked with a double fin-clip (LPLV and RPRV) in 1955 were observed the following year. There was no significant difference in survival between this group and 52 recaptures of 196 single fin-clips (chi-square = 1.11 with 1 d. f.; P = 0.52). The double fin-clips apparently survived as well as the single ones.

There was a great difference in survival of the various groups of latex injected fish a year following marking, however. A homogeneity test among the LOY, ROY, LPDY, and RPDY gave a chi-square value of 13.057 with 3 d. f. (P = less than 0.005). Both occiput injections were equivalent to one another (chi-square = 0.154 with 1 d. f.; P = 0.68) as were both posterior dorsal marks (chi-square = 0.081 with 1 d. f.; P = 0.79). However, the difference between the recapture rate of the types of latex marks was significant (Table 6). Only 4.1 percent of the occiput marks were observed a year after marking whereas 25.0 percent of the posterior dorsal marks were

ABLE 6. *Comparison of the survival of occiput and posterior dorsal latex-injected redear sunfish a year following marking.*

Latex mark	Total marked	Recaptures	Percentage recaptured
ciput	121	5	4.1
sterior dorsal	24	6	25.0

hi-square = 9.843 with 1 d. f.; P = less than 0.005.

en. There is little likelihood that these two groups represented random mples from a common population (chi-square = 9.843 with 1 d. f.; P = ss than 0.005).

The posterior dorsal marks were clearly superior to the injections made the occiput region. The rate of recapture of the former group corresponded ry closely with the overall return of the single and double fin-clips (av. = .3 per cent). The inferiority of the occiput marks was further substantiated y the lack of any 1956 recaptures of the fish marked LORe or RORe in eriod III of 1955.

There was some visual evidence that the occiput injections were not being tained. Late in the trapping period of 1955 an occasional individual was bserved which had a raw spot on the occiput region which resembled an pen sore. The latex spot was evidently creating a local irritation and was eing sloughed off. In 1956 the 1955 fin-clip recaptures were given a white cciput injection in order to recognize them if they were captured again. hese were examined very closely each time one was taken, and we observed even fish which had either incipient raw spots or a latex spot which was pulling out" of its place beneath the skin. No posterior dorsal mark was een which suggested this kind of difficulty. The sore spot may have become nfected causing weakness or death to the individual, or it may have healed. n either case, the fish could be recognized no longer. Obviously, the occiput ark should not be used in survival experiments which last a year or more.

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SIZE LIMITS IN LARGEMOUTH BLACK BASS MANAGEMENT

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ABSTRACT

A reanalysis of pertinent data on survival, natural mortality rates and rates of exploitation for largemouth black bass *(Micropterus salmoides)* is made. It is demonstrated mathematically that a size limit effective one year after the minimum size at which capture is practicable will eventually assure a greater number of large fish in the catch than is possible without a size limit under the conditions observed to date. Large fish are defined as those which are three years or more older than fish at the limiting size for capture.

INTRODUCTION

It has recently been vogue to reduce restrictive regulations for inland ort fisheries and size limits have been eliminated in many states for the rgemouth black bass, *Micropterus salmoides* (Lacepede). The apparent asons for relaxed regulations are that no protection of adults is needed order to maintain an adequate brood stock and that previously existing gulations have had no influence on fishing success. The second part of e statement bears more critical examination. An optimum catch (optimum hing success) may involve different requirements for various people and r various fisheries as has been pointed out by Allen (1954) who made ecial reference to the salmonid sport fishery. Some requirements of an ptimum catch may be defined as: (1) the greatest weight of fish which n be harvested on a sustained basis, (2) the greatest number of large sh which can be harvested with no regard for small fish, (3) the maximum umber of large fish in a catch which also includes some small fish. Objecve determinations of minimum size limits to satisfy the first, and perhaps e most universally acceptable definition, have been made by Ricker (1945) nd Saila (1956) for bluegill and chain pickerel respectively. For any shery in which a takeable size range extends to the region of increasing omass where growth rate greatly exceeds natural mortality rate, it seems robable that a significant reduction in the total weight of fish caught would ccur over a wide range of sizes below the best minimum size for maximum eight yield. Ricker (1945) has suggested that this statement may hold r the largemouth bass fishery in Indiana. It is obvious if one is not interested in small fish at all that a size limit at a value which barely satisfie an acceptable definition of large fish will provide the maximum numbe of these in the catch. The third definition will be considered further in thi paper. The outstanding critical analysis of size limits by Allen (1954), th comprehensive report on largemouth bass by Bennett (1954) as well a data obtained during a fishery survey of the inland waters of Rhode Islan by Saila and Horton (1957), have been utilized for this purpose. Notatio used herein follows that of Ricker (1948) to the extent possible.

Available Data

A negative exponential relationship between the numerical decline of th largemouth bass population and time has been assumed. Ricker (1949) ha already demonstrated that this relationship describes the mortality of som freshwater fish after they become vulnerable to a fishery. This relationshi can be defined in the general case as:

$$N = N_0 e^{-iT}$$

where N_0 is the original population, N is the population after time T an i is the total instantaneous mortality rate.

A portion of Table 19 from Bennett (1954) has been utilized to obtai certain numerical relationships. Since some of his data are obtained for tw years periods, it has been necessary to convert these to values expressed o an annual basis. The data and calculations are shown in Table 1.

The catch is defined as:

$$\begin{aligned} C \text{ (first year)} &= N_0 \mu \\ C \text{ (second year)} &= (N_0 e^{-i}) \mu \end{aligned}$$

where C is the catch and μ is the rate of exploitation.

Using the above relationships, a comparison is made of some of Ben nett's (1954) observations with results obtained by fitting his data to a empirical model which assumes exponential mortality and exploitation rat over the period considered. From Table 2, it is evident that the calculate values correspond well with the observations and use of the empirical defined relationship seems justified in this instance.

A summary of numerical values and symbols for sources of mortali derived from Bennett's data follows:

Category	Symbol	Numerical Val
Total annual mortality rate	a	0.65
Total instantaneous mortality rate	i	0.83
Rate of exploitation	μ	0.50
Instantaneous fishing mortality rate (in presence of a size limit)	p_2	0.74
Instantaneous natural mortality rate	q	0.09

TABLE 1. — *Data, calculations and relationships obtained from Table 19 of Bennett (1954).*

Period	Survival rates for two-year periods 2 s	Logarithm of 2 s
1945-7	0.13	9.1139-10
1947-9	0.28	9.4487-10
1949-51	0.18	9.2672-10

Geometric mean of 2 s = 9.2766-10 = 0.19

$1\text{-}2s = 2a$
$0.81 = 2a$
$1\text{-}2a = e^{-2i}$
$0.19 = e^{-2i}$
$i = 0.83$
$s = e^{-i} = 0.44$
$1\text{-}s = a = 0.56$

Period	Rates of exploitation (annual basis) μ	Logarithm of μ
1945	0.62	9.7952-10
1947	0.35	9.5428-10
1949	0.56	9.7482-10

Geometric mean of μ = 9.6954-10 = 0.50

$$p_2 = \frac{i\,\mu}{a} = \frac{(0.83)\ (0.50)}{0.56} = 0.74$$

$q = i\text{-}p_2 = 0.83\text{-}0.74 = 0.09$
$n = 1\text{-}e^{-q} = 1\text{-}0.91 = 0.09$
$m = 1\text{-}e^{-p_2} = 1\text{-}0.48 = 0.52$

TABLE 2.—*A comparison of actual observations and calculated values from a portion of Table 19 from Bennett (1954). Marked fish at the start of each period from Bennett's data exceed the minimum size limit.*

Period	Number of Fish Bennett's Data	Calculated Values
1945-47		
Number at start	647	647
Number remaining	84	123
Total deficit	563	524
Catch — 1945	404	326
Catch — 1946	88	142
Unaccountable loss	71	56
1947-49		
Number at start	392	392
Number remaining	110	75
Total deficit	282	317
Catch — 1947	137	196
Catch — 1948	107	86
Unaccountable loss	38	35
1949-51		
Number at start	1027	1027
Number remaining	190	195
Total deficit	837	832
Catch — 1949	575	514
Catch — 1950	148	225
Unaccountable loss	114	93

In the formulae which follow it is necessary to partition the relationshi $p + q = i$, which is given by Ricker (1948) into the following:

$p_1 + q$ = total instantaneous mortality rate in the absence of a size limi
$p_2 + q$ = total instantaneous mortality rate in the presence of a size limi

p_1 is the instantaneous fishing mortality rate in the absence of any size limi

In addition to these relationships obtained from Table 19 of Benne (1954), data from Table 6 of this same paper were used to calculate geometric mean value of the proportionate reduction in the catch (e pressed in numbers of fish) due to the existence of a size limit which w 10 inches in this case. It is possible to utilize these data to determine observed value for the proportionate reduction in catch due to a size lim because in the period of 1946-1950, fishermen were requested to bring all fish regardless of size. Separate records were kept for two size groups largemouth bass consisting of fish larger and smaller than 10 inches. Tab 3 illustrates an empirical value of 0.65 as the proportionate reduction catch due to a size limit of 10 inches. That is, with this size limit in effec the number of fish caught was, on the average, 35 per cent less than it w with no size limit. The proportionate reduction in catch due to a size lim has been designated as L by Allen (1954). He has shown that if the tot number of fish caught when a size limit is imposed is L times that caug when there is no size limit, then:

$$\frac{N_0 p_2 e^{-T_1 q}}{p_2 + q} = L \frac{N_0 p_1}{p_1 + q}$$

in which a previously undefined term is T_1.

The terms T and T_1 have been defined by Allen (1954) and are nece sary in determining whether size limits are effective in allowing the max mum number of large fish in a catch which also includes small fish. The are general terms used to derive formulae for the general case and numer cal values may be substituted for them in specific cases. A fish T years old than the minimum size practicable for capture is defined as a large fis A size limit exists at a value reached by the average fish T_1 years aft reaching the minimum size practicable for capture.

Numerical values of $T = 3$ and $T_1 = 1$, considered fairly typical Allen *(ibid.)* have been applied to some available largemouth bass dat Table 4 illustrates these values which were applied to the observed grow of largemouth bass from Table 13 of Bennett (1954) and the calculated growth of largemouth bass from Rhode Island by Saila and Horton (1957). It is to be noted from this table that although the growth rates in these two areas differ markedly, values for the minimum size practicable for capture and the minimum size of large fish do not appear unreasonable.

For a sport fishery, and in some instances for a commercial fishery, it seems economically or aesthetically desirable to assure a maximum number of large fish in a catch also containing a proportion of small fish. In this case, large fish are defined as those fish three years older than the minimum at which capture is practicable. Small fish are defined as those fish between the minimum size where capture is practicable and three years beyond this value.

TABLE 3.—*Geometric mean of the proportionate reduction in catch due to a size limit of 10 inches. From Table 6 of Bennett (1954).*

Year	Ratio (largemouth bass > 10 inches/total)	Logarithm of ratio
1946	$\frac{206}{366} = 0.57$	9.7559-10
1947	$\frac{149}{181} = 0.82$	9.9138-10
1948	$\frac{363}{648} = 0.56$	9.7482-10
1949	$\frac{577}{594} = 0.97$	9.9868-10
1950	$\frac{236}{515} = 0.46$	9.6628-10
	Geometric mean = 9.8135-10 = 0.65 = L	

TABLE 4.—*Growth rates of largemouth bass from two areas. A minimum size limit occurring approximately one year beyond the minimum size practicable for capture and the approximate size of large fish three years older than the minimum size practicable for capture) are illustrated.* $T_1 = 1$ *and* $T = 3$ *in both cases.*

Source	Average Total length in inches at end of each growing season							
	1	2	3	4	5	6	7	8
Bennett (1954) Table 13, p. 255.	8.1	10.3	12.6	13.7	14.3	16.7	17.4	18.8
	↑ Minimum size practicable for capture	↑ Approx. minimum size limit		↑ Minimum size of large fish				
Source	**Average calculated total length at annulus**							
	I	II	III	IV	V	VI	VII	VIII
Rhode Island data. Saila and Horton (1957)	3.0	6.4	9.3	11.8	14.4	15.6	16.7	18.1
		↑ Minimum size practicable for capture	↑ Approx. proposed size limit		↑ Minimum size of large fish			

The expression "a maximum number of large fish in a catch containing a proportion of small fish" is considered further. As is shown below, the number of large fish in a catch containing small fish apparently conforms to an equation of exponential form, which expressed in the general case is:

$$P_{\text{large}} = ke^{mx}$$

where P_{large} is the numerical proportion of large fish in the catch, m is the fishing mortality rate expressed on an annual basis and k as well as x are constants. It is appreciated that the exponential relationship postulated for the proportion of large fish in the catch is an obvious oversimplification of an intricate biological phenomenon. For example, in the model it is impossible to consider differences in the efficiency or habits of fishermen, differences in actual availability of various sizes of fish or differential mortality due to changes in population structure. In spite of these shortcomings it seems desirable to deduce the consequences of even a simple hypothesis since this permits testing assumption against reality.

The empirically determined values for the proportion of large fish in the catch are:

$$P_{\text{large}} \text{ (no size limit in effect) } = 0.99e^{-5.10m}$$

$$P_{\text{large}} \text{ (Size limit at } T_1 = 1) = 0.77e^{-0.50m}$$

The numerical values in these equations were obtained by holding the following values constant:

n = natural mortality rate $\cong$ 10 percent

L = proportionate reduction in catch due to size limit = 0.65

$T = 3$ = large fish by definition

$T_1 = 1$ = minimum size limit imposed one year beyond minimum size practicable for capture

N_0 = number of fish (1000 for purposes of computations) reaching minimum size practicable for capture

m = fishing mortality rate — varied from 0.05 - 0.95

The annual natural mortality and fishing mortality rates were transformed into instantaneous values labeled q and p_1 respectively. The following equations were then solved:

Total number caught (no size limit) $= \frac{N_o p_1}{p_1 + q}$

Number of large fish (no size limit) $= \frac{N_0 p_1 e^{-(p_1 + q)\,T}}{p_1 + q}$

$p_2 =$ new fishing mortality rate with a size limit $= \frac{qL}{(1 + q/p_1)e^{-qT_1} - L}$

Total number caught (size limit in effect at $T_1 = 1$) $= \frac{N_0 p_2 e^{-T_1 q}}{p_2 + q}$

Number of large fish (size limit in effect at $T_1 = 1$) $= \frac{N_o p_2 e^{-Tq + p_2\,(T - T_1)}}{p_2 + q}$

These equations were solved for nine separate values of m and the results are shown in Figure 1. It is evident from this figure that under the conditions described, the proportion of large fish never falls to < 0.5 with a size limit in effect at $T_1 = 1$. However, with no size limit, the proportion of large fish is virtually nil under the observed fishing mortality rate of 0.5 taken from Bennett's extensive data. It also appears from this figure that the value of a size limit in allowing a greater proportion of large fish in the catch increases rapidly with increasing fishing mortality rates.

The observed value of 0.65 for L, 3 for T and 1 for T_1, as well as a range of values for q (the instantaneous natural mortality rate) have been substituted in appropriate equations given by Allen (1954). These equations are:

$$p_1 = \frac{X}{1 + 1 - X^2 \, \frac{T\,(e^{-qT_1} - L)}{qe^{-q-T_1}\,(qT_1 + 1)}}$$

$$\text{where } X = \frac{2qe^{-qT_1}(qT_1 + 1)}{L(1 + qT) - e^{-qT_1}(qT + qT_1 + 1)}$$

$$l = \log n\ L$$

$$s = e^{-(p_2 + q)}$$

$$R = \frac{p_2}{p_2 + q}$$

The terms of these equations have been previously defined. Substitution in these equations of 0.65 for L, 3 for T, 1 for T_1 and various values for q permits one to construct a curve (Figure 2) which defines the zones above and below which a size limit will allow a larger or smaller catch of large fish. This figure illustrates the situation when a fishery manager agrees to be satisfied with 65 per cent of the total physically takeable catch (numbers of fish) in the interest of catching a greater number of large fish. The curve in the figure illustrates values of s and R for which the catch of large fish would be numerically the same with and without a size limit in effect where $L = 0.65$, $T_1 = 1$ and $T = 3$. Points falling below the curve (shaded

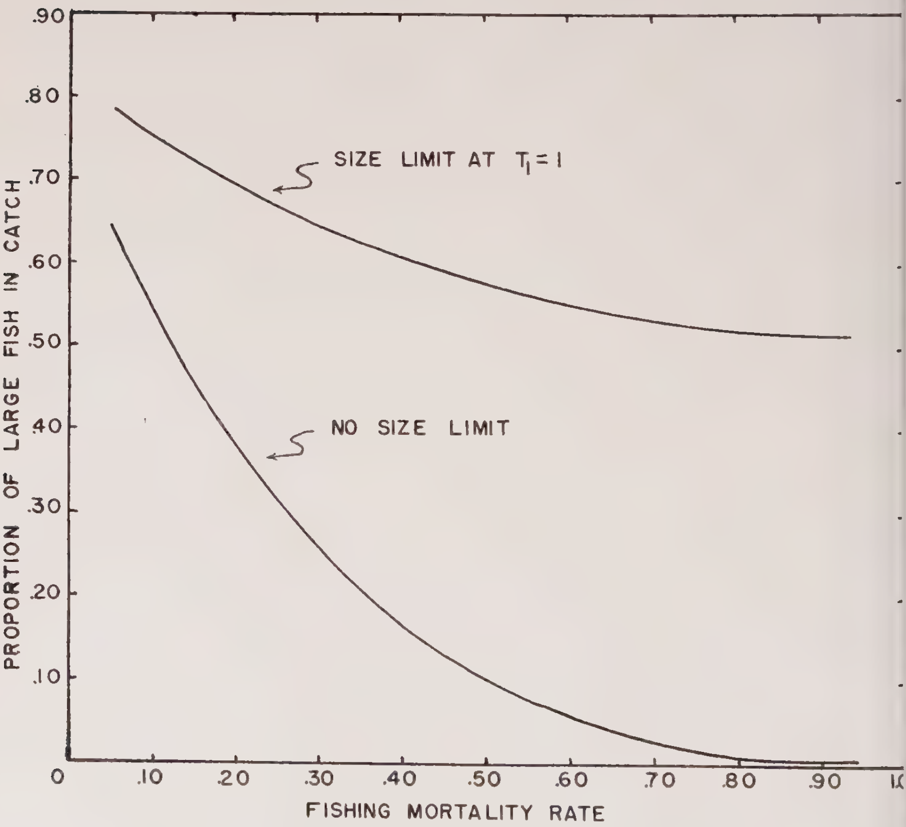

FIGURE 1.—Proportion of large fish in the catch with and without a size limit at $T_1 = 1$ calculated for various rates of fishing mortality.

area) indicate values of s and R for which removal of a size limit at $T_1 = 1$ would increase the number of large fish in the catch.

Values for the annual survival rate (s) and the proportion of takeable fish ultimately caught (R) as calculated from Bennett's data have been located on this figure. It is to be noted that the point described by these values lies above the curve, indicating a greater catch of large fish is possible in the presence of a size limit. The vertical line in the figure indicates the range of values on which Rhode Island data obtained from Saila and Horton (1957) could fall. The R value in this case was obtained by assuming a constant proportion of any given year class is captured each year. In the above instance, the proportion of takeable fish ultimately caught falls to the left of the entire curve. Hence, any value of s would not move the point into the shaded area.

It is indeed unfortunate that so little critical data on mortality components are available. The following exploitation rates for largemouth bass and their sources are listed for comparative purposes:

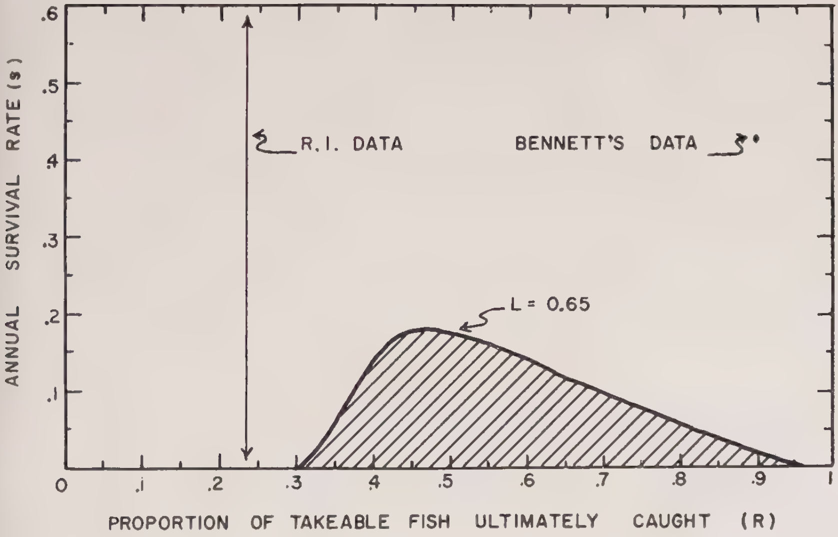

FIGURE 2.—Critical values of s and R where $s = e^{-(p_2 + q)}$ and $R = \frac{p_2}{p_2 + q}$ Points falling in the shaded area are those for which size limits would decrease the numerical yield of large fish. Points lying above the shaded area are those which permit a greater catch of large fish in the presence of a size limit. $L = 0.65$, $T_1 = 1$ and $T = 3$. The L value is empirically obtained from Bennett (1954).

Value	Water	Source
0.17	Spear Lake, Indiana (combined data)	Ricker (1945)
0.185	Norris Reservoir, Tennessee	Eschemeyer (1942)
0.20	Shoe Lake, Indiana	Ricker (1942)
0.21	Sandy Pond, Rhode Island	Saila and Horton (1957)
0.32	Spear Lake, Indiana	Ricker (1955)
0.50	Ridge Lake, Illinois	This paper from Bennett (1954)

An annual natural mortality rate (n) of 0.09 has been obtained from Bennett's work and Swingle (1950) has indicated an average annual natural mortality rate of 0.20 for largemouth bass in ponds.

The above figures on exploitation and natural mortality can be utilized in a crude fashion to demonstrate their relationships in the figure. In Figure 2, it is noted that an annual survival rate (s) of less than 0.18 must be combined with a narrow range of values of (R), the proportion of takeable fish ultimately caught, in order to fall into the area where more large fish would be caught in the absence of a size limit than in its presence. Actually, values of n (the annual mortality rate from natural causes) ranging from 0.26-0.47 combined with observed rates of exploitation are required in order to fall in this area. These values of n are more than have been reported to date from any source.

From available data it seems rather unlikely that the removal of size limits for largemouth bass has had no effect on the fishery in areas where this restrictive regulation has been removed. As a matter of fact, the effect of the removal of size limits has probably been adverse if the greatest number of large fish in a catch also containing small fish is considered a desirable management objective.

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THE DEVELOPMENT OF THE FISH POPULATION IN A NEW FLOOD-CONTROL RESERVOIR IN MISSOURI, 1948 TO 1954

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ABSTRACT

Changes in the fish population in Clearwater Lake during the first 7 years after impoundment, 1948 through 1954, are described. This flood-control reservoir of 1,650 acres on Black River in the Ozark Highland of Missouri was completed by the Corps of Engineers, U. S. Army, in 1948. It is mostly shallower than 30 feet, and the water is moderately hard (M. O. alkalinity 97-106 p.p.m.) and clear (turbidity usually less than 7 p.p.m.).

Fish samples were obtained by the use of nets, seines and rotenone, and from anglers' catches. Relative numbers, growth rates, and abundance in the anglers' catches are discussed for crappies, smallmouth bass, largemouth bass, bluegills, longear sunfish, rock bass, warmouth, green sunfish, redhorse suckers, gizzard shad, bullheads, channel catfish, and carp.

All fish species numerically important in the population by 1954 had spawned successfully at least once by 1952, so it is assumed that the carrying capacity of Clearwater Lake for the species complex present was reached by 1952; five years after the lake was impounded. The population had become fairly well stabilized by 1954.

In several instances only one of two or more related species became numerous. The white crappie was the most abundant species in the sport fishery from 1951 on, despite a high natural mortality among fish older than three years. Black crappie did not succeed in the lake. Recruitment of smallmouth bass was poor and few were caught after 1949. The 1948 year class provided most of the largemouth bass catch by fishermen during the first three years after which, despite two large crops of young of the year, angling success for the species declined noticeably. Bluegill spawning success and survival was good every year and bluegills have been important annually in the sport fishery, with the 1948 and 1949 broods abundant in the catches. Rapid growth of longear and green sunfishes in 1948 was responsible for a sizeable creel of these species in 1949 but in subsequent years few reached catchable size. Rock bass were numerically important in the population only in 1949 and 1950.

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Other centrarchids did not fare as well although successful year classes of warmouth have been observed. Small sunfishes under 4 inches, particularly bluegills and longear sunfish, were recovered in large numbers in coves treated with rotenone.

After 1948, black bullheads outnumbered yellow bullheads and large numbers were caught by anglers each year. Channel catfish did not spawn successfully until 1952; few flathead catfish were captured. Golden redhorse suckers outnumbered black and northern pealip redhorse. Carp are believed to have spawned successfully in 1948 and 1951 whereas gizzard shad produced their first large brood in 1950.

All fish grew rapidly in 1948, the first year of impoundment, but growth increments declined noticeably thereafter except for smallmouth bass. As late as 1953 all species except gizzard shad grew better in the reservoir than in the river. River shad had a shorter life span than those in the lake.

Trends in abundance for the principal small fishes are also considered. Four species numerically dominated this segment of the population nearly every year: brook silversides, bluntnose minnow, bigeye shiner, and whitetail shiner. However, a few of many other species of small fishes were present and constituted a potential stock for a population upsurge in response to a sudden environmental change.

INTRODUCTION

Completion of Clearwater flood-control reservoir on Black River, Missouri, in 1948 by the Corps of Engineers, U. S. Army, provided an opportunity to study the changes in a fish population with the change in habitat from river to lake.

In its upper reaches Black River is a spring-fed, clear, Ozark Highland stream with an average discharge of less than 5,000 second-feet and a mean velocity of less than 3.6 second feet. Occasional flash floods occur. The river channel has a length of 291 miles of which 171 miles are in Arkansas where it enters the White River. Campbell and Funk (1953) give a comprehensive description of Black River and its watershed.

Clearwater Dam, which impounds the reservoir, is located some 26 miles from the headwaters. The main Black River arm of the reservoir is 6 miles long while the arm of Logan Creek, a tributary of the Black, is 3 miles long. Clearwater Lake has an area of 1,650 acres at conservation-pool level and a total storage area of 10,350 acres. The lake is shallow so that, at conservation-pool level, only a small portion is deeper than 30 feet. Turbidity readings were usually less than 7 p.p.m. and methyl-orange alkalinity determinations varied between 97 and 106 p.p.m. Thermal and chemical stratification in mid-summer occurred only in the deep, submerged borrow pits near the dam. A temperature series in July, 1952, ranged from 86.0°F. at the surface to 54.5°F. at 48 feet; in April, 1950 from 52°F. at the surface to 48°F. at 45 feet.

The problems connected with large impounded waters have been studied for many years by fishery investigators. Ellis (1937, 1942), Wickliff and Roach (1937), Wiebe (1938, 1941), Tarzwell (1941), Eschmeyer (1942, 1950), Buck and Cross[3], Hall and Jenkins[4], and many others have studied various effects upon stream environments by impoundment of the water.

Four published papers devoted considerable attention to specific aspects of the early history of Clearwater reservoir: Martin and Campbell (1953), O'Connell and Campbell (1953), Kathrein (1953), and Lane (1954). This paper introduces additional data to give a more complete picture of the development of the fish population and fishery in Clearwater Lake during the first 7 years of its existence.

METHODS OF SAMPLING FISH POPULATION

Fishes were collected by means of nets, seines, and rotenone in the summer and fall, 1948-1954. Gill nets were of both single mesh and graded mesh sizes ranging from ¾ to 2½ inches (bar measure), 6-foot deep, and 150 to 300 feet long. Linen nets were used until 1954; nylon nets also were fished in 1953 and used in preference to linen nets in 1954. Hoop nets of 1¼- or 2½-inch-mesh webbing (bar measure) had a 4-foo front hoop and were baited with cottonseed cake. Beginning in 1951, these nets were fished with 12-foot wings and 75-foot leads. Three-foot and 4-foot trap nets with 100-foot leads, similar to the net described by Crowe (1950), were fished each year except 1948. Trammel nets were set in 1948 and 1949. All nets were set on the bottom and perpendicular to the shore.

Small fish collections were made in two ways. Between 1948 and 1952 periodic seining was done throughout the summer months. From 1950 to 1954 sites which were selected in 1950 were seined annually with a 25- foot, ¼-inch mesh bag seine. High water prevented the seining in mid-July in 1951.

Rotenone was applied in small coves, the total acreage treated ranging between 1.34 and 1.63 acres each year. Fish were recovered for three days following each application.

An intensive creel census has been in operation on Clearwater Lake since 1949 (Kathrein, 1953). Some of these data are the only source of information on trends in relative abundance of adult black bass and rock bass *Ambloplites rupestris.*

The growth increments for nine of the species which appear in this paper were computed from body-scale relationships calculated either for the reservoir population or the Black River population. A linear relationship was assumed for green sunfish, warmouth and carp with respective correction factors of 0.8, 0.8 and 1.0 inch.

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[3] Buck, Homer and Frank Cross. 1952. Early limnological and fish population conditions of Canton Reservoir, Oklahoma, and fishery management recommendations. Reproduced by the Research Foundation, Okla. A&M College, 110 pp.

[4] Hall, Gordon E. and Robert M. Jenkins. 1953. Continued fisheries investigation of Tenkiller Reservoir, Oklahoma, during its first year of impoundment, 1953 Okla. Fish. Res. Lab. Rep., No. 33, 54 pp.

PRE-IMPOUNDMENT CONDITIONS

Pre-impoundment studies of the fish population in Black River during the year prior to closure of the dam were reported by Martin and Campbell (1953), Funk and Campbell (1953), and Patriarche and Lowry (1953). Twenty of the 68 species of small fishes collected by repeated seining were minnows. They comprised 77 percent of the total number of fishes collected. Among the minnows, the bleeding shiner, *Notropis zonatus,* comprised one-third of the total number while the bigeye chub, *Hybopsis amblops,* white-tail shiner, *Notropis galacturus,* and bigeye shiner, *Notropis boops,* together constituted about 41 percent of the minnow collections. Also important numerically were the young of longear sunfish, *Lepomis megalotis.* black redhorse, *Moxostoma duquesni,* golden redhorse, *Moxostoma erythrurum,* and hog sucker, *Hypentelium nigricans.*

Smallmouth bass, *Micropterus dolomieu.* and rock bass were the dominant predators in the stream population. Other predacious species captured or known to have been present, although in considerably fewer numbers, were largemouth bass, *(Micropterus salmoides),* walleye *(Stizostedion vitreum),* sauger *(Stizostedion canadense),* grass pickerel *(Esox vermiculatus),* longnose gar *(Lepisosteus osseus),* black crappie *(Pomoxis nigro maculatus).* white crappie *(Pomoxis annularis)* and flathead catfish *(Pilodictis olivaris).* Gizzard shad *(Dorosoma cepedianum).* redhorses, longear sunfish, and hog suckers were abundant. Bluegills *(Lepomis machrochirus).* bullheads *(Ameiurus melas* and *A. natalis),* black buffalo *(Ictiobus niger),* smallmouth buffalo *(Ictiobus bubalus),* green sunfish *(Lepomis cyanellus),* spotted sunfish *(Lepomis punctatus),* carp *(Cyprinus carpio),* and mooneye *(Hiodon tergisus)* were present in limited numbers.

Relatively slow rates of growth were reported by Patriarche and Lowry (1953) for rock bass, longear sunfish, and green sunfish in Black River prior to impoundment. The growth rate of smallmouth bass was considered average for Ozark streams in Missouri.

POPULATION AND CATCH TRENDS OF LARGER GAME AND NON-GAME FISHES

No attempt was made to estimate the size of the entire fish population in Clearwater Lake. Rather, trends in relative abundance were followed, using netting, seining, poisoning, and creel census data. On the basis of experience gained on Clearwater Lake and other Missouri reservoirs (Patriarche, 1953), data supplied consistently by a particular method for a species were deemed reliable as an index of relative abundance. Insofar as possible, sampling conditions were standardized, not only for the netting periods but also for the seining surveys and rotenone collections. By adhering to the same seasonal schedule for a partcular kind of sampling method, the effect of fluctuations due to seasonal movements or recruitment were believed to have been minimized.

CRAPPIE

Although a few black crappie were taken from the lake until 1951, since that year only white crappie have been caught. Similar dominance of white crappie over black crappie is common in nearly all large Missouri reservoirs. Presumably white crappie spawned successfully in Clearwater Lake in 1948 in about 150 acres of water impounded before June, but netting data indicated that the first sizeable crop was spawned in the reservoir in 1949, and that there was an exceptionally large year class in 1951. The rapid increase in numbers of crappie in Clearwater Lake was shown in trap-net catches and anglers' catches (Table 1). By 1951 the crappie was the most numerous species caught by fishermen and they have retained that position since. However, the increase in the crappie catch may not reflect an actual increase in population size since according to population estimates using the mark and recapture method of Petersen the number of crappie 7 inches long or longer present on May 1, 1951 and again in 1954 were 132,000 and 118,650 respectively.

TABLE 1.—*The rate of catch of white crappie by hook and line and trap nets in Clearwater Lake, 1949-1954.*

[The trap net rates of catch are expressed as number of fish caught per overnight set.]

	1949	1950	1951	1952	1953	1954
Estimated number creeled	6,325	14,850	49,750	20,650	60,700	77,550
Number per 100 hours of still fishing	10	16	30	22	57	57
Trap net rate of catch	7.3	13.3	5.5	22.7	21.0	14.0
Trap net catch rate by age group:[1]						
I	5.0	12.2	3.3	19.0	9.8	3.1
II	trace	0.9	1.9	3.0	10.6	10.0
III	—	trace	trace	trace	0.6	0.9

[1]Not shown is Age Group 0. Except for 1949, very few fingerling crappie have been caught in the nets. In 1949 fast-growing young-of-the-year crappie were taken at the rate of 2.3 fish per set. One 4-year-old crappie was taken in 1954.

It appeared that natural mortality among white crappie was high. The rate of catch in the nets of age-group III fish was relatively good in the spring but poor in the fall. Only one 4-year-old crappie was taken in trap nets between 1949 and 1954, and 75 four-to-six-year-old crappie in April 1955. Trap nets are capable of taking older crappie in the fall for they have done so in other Missouri impoundments. Since less than 10 percent of the tagged fish have been caught by anglers each year, the apparent high mortality must be the result of natural causes. Kelley (1953) obtained similar evidence of a high natural mortality for white crappie in the Mississippi River.

According to Witt[5] the growth rate of crappie was excellent in 1948, the first year of impoundment. However, by the following year there was a marked decline to a level which has been maintained by succeeding broods through 1953 (Table 2). Both the 1948 year class and the small 1947 year class which was spawned in the river continued to make good growth through their fifth year of life. It is suggested that the abrupt decline in the growth rate of young of the year after 1948 resulted from the competition for food with the large crops of sunfishes and crappie that were produced in the new reservoir.

TABLE 2—*Average growth increment in inches in each calendar year for four age groups of white crappie in Clearwater Lake (1948-1953).*
[Number of fish in parentheses. Data partly from Witt (1952)]

	Calculated increment					
Age group	1948	1949	1950	1951	1952	1953
0	5.4 (133)	3.5 (196)	2.8 (170)	3.5 (164)	3.5 (131)	3.4 (26)
I	6.3 (7)	4.2 (70)	5.4 (120)	4.6 (130)	3.9 (78)	3.6 (75)
II		2.5 (7)	3.3 (40)	3.2 (44)	3.2 (41)	2.7 (22)
III			2.7 (4)	1.6 (7)	1.2 (6)	1.4 (1)

SMALLMOUTH BASS

Pre-impoundment collections disclosed that smallmouth bass greatly outnumbered largemouth bass in Black River. However, in the reservoir smallmouth bass declined to a point where they were no longer abundant in the sport fishery. In 1949, an estimated 2,500 were caught by anglers (Kathrein, 1953), but since 1950 only about 200 have been caught each year.

This decrease in smallmouth bass appears to result from poor survival of young. The 1948 year class, which spawned prior to the filling of the reservoir, provided most of the smallmouth bass catch from 1949 to 1952. Although a few fingerlings (young of the year) were seined each year, no large recent year class has been observed in the reservoir to date.

The growth rate of smallmouth bass in Clearwater Lake was excellent (Table 3), especially for young of the year and yearlings, and exceeded that for the same species in the river. However, difference in growth in length between stream and reservoir populations for older age groups was slight. Although growth rate of fingerling white crappie declined noticeably after 1948, that of smallmouth bass young of the year continued to be good. This difference in growth between the species may reflect a difference in population density: namely, an increase in population density among crappie and a population decline for smallmouth bass.

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[5] Witt, Arthur Jr., 1952. Age and growth of the white crappie, *Pomoxis annularis* Rafinesque, in Missouri. Unpublished Ph.D. dissertation, Univ. of Missouri, Graduate School. 213 pp.

TABLE 3.—*Average calculated growth increment in inches of smallmouth bass in Clearwater Lake (1948-1953) compared with average growth increment in Black River prior to impoundment in 1948.*

[Number of fish in parentheses. River values from Patriarche and Lowry (1953)]

Age group	Calculated increment						Lake average 1948 to 1953	Black River average
	1948	1949	1950	1951	1952	1953		
0	4.9 (52)	4.8 (11)	4.3 (5)	4.2 (9)	4.7 (10)	4.8 (1)	4.6	2.7
I	4.5 (10)	3.2 (45)	3.9 (8)	4.3 (3)	5.1 (7)	5.3 (1)	4.4	3.2
II	4.5 (6)	2.8 (7)	2.8 (27)	3.1 (4)	4.1 (2)		3.2	3.0
III	3.1 (6)	2.1 (4)	2.8 (3)	2.8 (4)	3.0 (1)		2.7	2.4
IV	2.6 (3)	1.4 (3)	2.3 (4)	2.8 (3)	2.9 (4)		2.4	2.4

LARGEMOUTH BASS

In Clearwater Lake the largemouth bass is the most numerous large predator. Although the main body of the reservoir filled after the bass spawning season, there was a high rate of survival of fingerling largemouth bass spawned in the river and in the 150 acres of water impounded early in the year. This natural crop and fish from a stocking of 85,000 fingerlings by the Missouri Conservation Commission made up the year class that provided most of the angling catch during the first three years after impoundment. As late as 1954 the 1948 year class comprised an estimated eight percent of the bass catch (Table 4).

Two excellent crops of largemouth bass fingerlings have been observed since the impoundment was created, one in 1950 and one in 1953. Only in 1952 was there a poor survival of the bass spawn. Receding water levels have a detrimental effect upon largemouth bass spawning. The spawning period for largemouth bass in Clearwater Lake is believed to be during the first three weeks in May according to Nichols[6] and data furnished by the Corps of Engineers show that only in 1950 and 1953, the years of the greatest spawning success, were water levels either stable or rising during the spawning period. In the year of poorest survival, 1952, spring water levels receded sharply. There also were small fluctuations in the water level during the spawning season of 1954 but the numbers of young bass in the seine hauls were considered average.

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[6] Nichols, Hudson M., 1953. The age and growth of the largemouth bass, *Micropterus salmoides* (Lacepede) in a new flood control reservoir in Missouri. Unpublished Masters thesis. University of Missouri, Graduate School, 51 pp.

TABLE 4.—*Percentage age-composition of largemouth bass from the Clearwater Lake angling catches—1950 to 1954.*
[Percentages in italics are those of the 1948 year class]

Age group	1950	1951	1952	1953	1954
0	5	—	3	—	—
I	25	6	11	13	12
II	*66*	31	37	39	34
III	2	*57*	36	26	24
IV	—	4	*13*	20	10
V	2	tr.	tr.	*1*	10
VI	—	—	—	tr.	*8*
Number in sample	122	209	279	354	97

Despite satisfactory spawnings in the reservoir, largemouth bass fishing has declined since 1949. Even though the majority of anglers now seem to fish mostly for crappie (85 percent of the anglers in 1954 were still-fishing with live bait) those who prefer bass fishing have had poor success in recent years.

The number of bass caught per 100 hours of fishing with artificial lures declined successively from 1949 to 1954 as follows: 19, 17, 8, 10, 5 and 1. A failure of much of the big 1950 crop to survive to catchable size probably is responsible for the downward trend in bass fishing success. Data in Table 4 plus unpublished figures from other Missouri reservoirs indicate that 2- and 3-year-old bass comprise about two-thirds of the bass caught by hook and line. In 1952, 15,000 bass between 8 and 10 inches long were stocked in the lake, but this stocking failed to check the downward trend in the angler's catch.

The calculated growth increments of four age groups of largemouth bass in the reservoir appear in Table 5. Young-of-the-year and yearling bass grew rapidly in 1948 and young-of-the-year bass made good growth in subsequent years until 1951, after which growth rate declined. The first four year classes of bass spawned in Clearwater Lake (1948-1951) averaged more than 13 inches in total length at the end of their third year of life.

OTHER CENTRARCHIDS

The population of fishes in Black River also included rock bass, spotted sunfish, bluegills, green sunfish, longear sunfish, and warmouth *(Chaeno-*

TABLE 5.—*Average calculated growth increment in inches in each calendar year for largemouth bass in Clearwater Lake (1948-1953).*

[Number of fish is shown in parentheses. Data partly from Nichols (1953)]

Age group	Calculated increment					
	1948	1949	1950	1951	1952	1953
0	6.6 (441)	6.1 (454)	6.3 (262)	5.4 (185)	5.5 (88)	5.8 (15)
I	7.8 (14)	3.8 (411)	4.5 (389)	5.0 (240)	5.1 (170)	5.1 (39)
II	3.1 (2)	3.0 (13)	2.8 (267)	2.8 (273)	2.3 (108)	2.5 (23)
III	3.6 (1)	2.5 (1)	1.4 (11)	2.0 (90)	1.5 (17)	1.4 (10)

bryttus coronarius). Of these, only bluegills have made important contributions to the anglers' catches in Clearwater Lake every year. The annual estimated total catches of bluegills by hook and line from 1949 to 1954 were as follows: 11,025; 15,125; 24,350; 13,100; 18,500; 7,600. The quality of bluegill fishing expressed as numbers caught per 100 hours of still-fishing between June 1 and August 31 for the same series of years was: 20, 26, 25, 25, 55, and 22. This 3-month period consistently has been the best time for bluegill fishing in the reservoir.

More than 10,000 longear and green sunfishes were caught by anglers in 1949 but few were taken in later years (Kathrein, 1953). Similarly, an estimated 1,200 rock bass were caught by fishermen in both 1949 and 1950 but relatively few have been caught since then. Spotted sunfish and warmouth have never been numerically important in the sport catch.

Rock bass and spotted sunfish failed to spawn successfully in the lake but warmouth were successful in spawning and survival was good in 1948, 1950, and 1953.

Bluegills and longear sunfish became extremely abundant in Clearwater Lake soon after impoundment. As pointed out by Martin and Campbell (1953), extensive beds of pondweeds which developed in 1949 provided additional cover which favored the survival of bluegills that year. The censusing of coves with rotenone showed that sunfishes continued to be abundant after 1949. Sunfishes under 4 inches were recovered each year at rates of more than 7,000 per acre with a high of 12,714 per acre in 1954 (Fig. 1). Green sunfish and warmouth were greatly outnumbered by bluegills and longear sunfish in these censuses (as much as 100 to 1 in 1954). The large numbers of small sunfish in Clearwater Lake appear even more striking when compared with numbers from other Missouri reservoirs (Fig. 1).

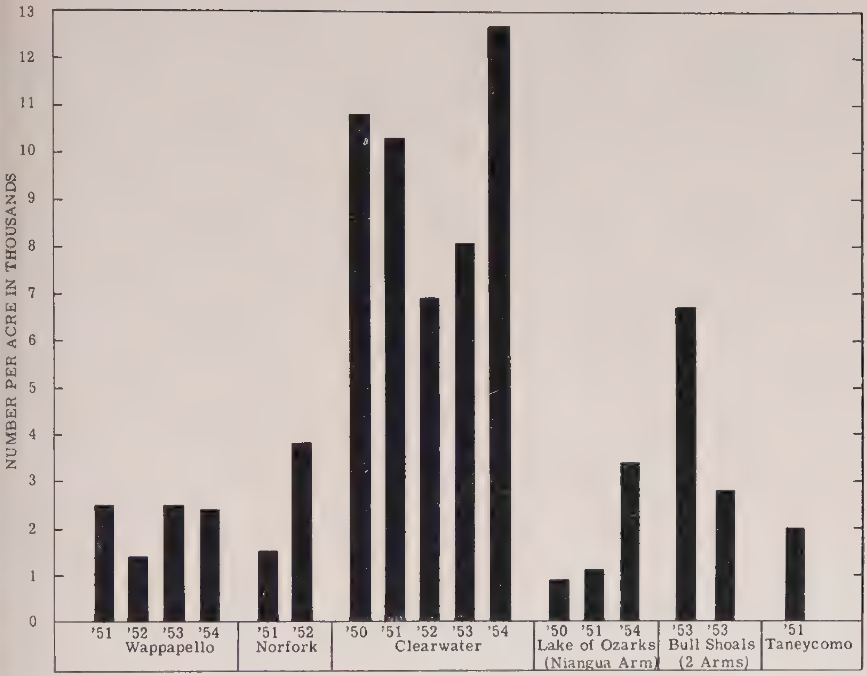

FIGURE 1.—Number per acre of sunfish under 4 inches total length recovered by use of rotenone on selected areas of six reservoirs in Missouri, 1950-1954.

Growth rates for several age groups of bluegills, longear sunfish, green sunfish, and warmouth were exceptionally rapid in 1948 (Fig. 2), so that many of these fish were large enough to be caught in 1949. Green sunfish one and one-half years old, for example, were 6.5 inches long in 1949. In subsequent years a slower rate of growth has meant that few fish of these species reached a desirable size. The rate of growth of longear sunfish in the reservoir was better than in Black River. The average length of 3-year-old fish in 1953 was 4.4 inches, 0.9 inch longer than Black River longear sunfish of the same age.

The rapid growth rates of fish in 1948 (Fig. 2) must have resulted from the large food supply available to the expanding population in the newly flooded reservoir. Terrestrial invertebrates were available in abundance in 1948, and a substantial benthic population had developed (O'Connell and Campbell, 1953). The combination of an expanding fish population and a relatively stabilized bottom fauna population resulted in diminished growth rates of these species after 1948.

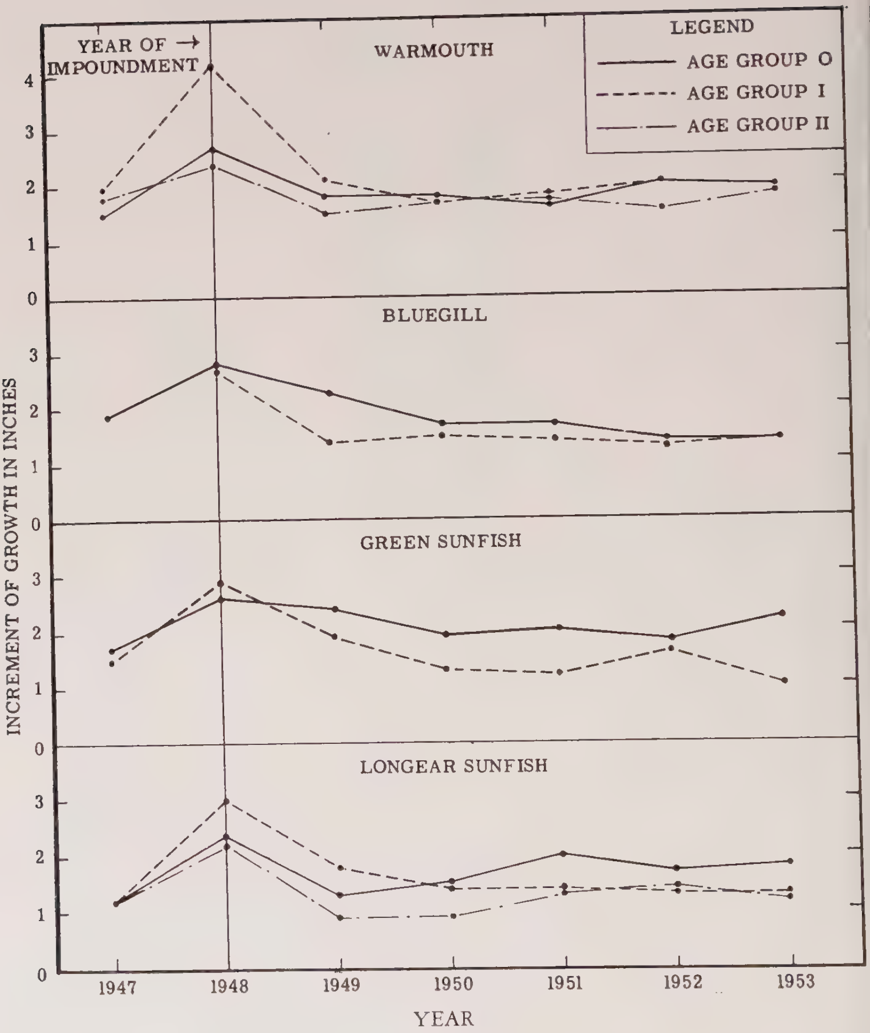

FIGURE 2.—The average calculated annual growth increment in inches for several age groups of four species of sunfish in Black River (1947) and in Clearwater Lake (1948-1953).

[Bluegill data taken in part from Lane (1954)]

REDHORSE SUCKERS

Four species of redhorse suckers were identified in the pre-impoundment area of Black River. Golden redhorse were judged to be twice as abundant as the black redhorse. The pealip shorthead redhorse *(Moxostoma aureolum pisolabrum),* and the river redhorse *(Moxostoma carinatum)* were not numerous and they have not been taken in the lake.

Golden redhorse are thought to be better adapted to reservoir conditions than black redhorse since they are the dominant redhorse species in Clearwater Lake as well as in other Missouri impoundments. From 1949 to 1954 the numbers of golden redhorse captured per 24-hour gill-net set in Clearwater Lake were as follows: 1.3, 1.5, 1.5, 1.1, 3.3, and 5.9. Comparable figures for black redhorse were: 1.9, 1.3, 0.7, 0.6, 0.8, and 0.0. The 1951 and 1952 year classes were responsible for the increases in the gill-net catches of golden redhorse in 1953 and 1954. Large numbers of small black redhorse were recovered in coves censused with rotenone in 1952, 1953, and 1954, which suggests that the species will continue in the reservoir.

The growth rates for all age groups of both redhorse species in the new reservoir in 1948 were greater than in the stream in 1947. Like many other fishes, however, the rates of growth for both species declined between 1948 and 1953. By 1953 redhorse of age group II and older grew slower than river fish (Table 6). The 1948 brood of golden redhorse averaged 13.1 inches in length after 3 years of life whereas 3-year-old fish of the 1951 year class averaged 11.4 inches. Comparable figures for black redhorse were 11.8 and 9.9 inches respectively.

TABLE 6.—*The average increment of growth (inches) for four age groups of golden and black redhorse suckers in Black River compared with the increments made in 1948 and 1953 in Clearwater Lake.*

Age groups	Golden redhorse			Black redhorse		
	River 1947	Reservoir 1948	Reservoir 1953	River 1947	Reservoir 1948	Reservoir 1953
0	2.4	3.0	—	2.8	3.6	—
I	3.7	6.8	4.3	3.5	5.8	3.9
II	4.0	4.9	3.7	3.4	4.5	2.3
III	2.6	3.3	1.5	2.4	3.2	1.6

GIZZARD SHAD

Shad were numerous in collections made in the pre-impounded section of Black River. Since shad are abundant in other Missouri reservoirs, it was reasonable to assume that this fish would adapt readily to Clearwater Lake. Between 1950 and 1954 shad over 8 inches long were recovered from coves treated with rotenone at rates varying from 46 to 158 pounds per acre, a standing crop larger than that of any other species.

Despite evidence of successful shad spawning in each year except 1953, the 1948 year class dominated the gill-net catches from 1948 to 1952 (Table 7). In 1953 and 1954, the 1948 year class was exceeded only by that of 1949. Shad abundance was judged from catches of gill nets of 1½-inch and 1¾-inch mesh.

The average growth increments in inches for shad in the Black River prior to impoundment and in Clearwater Lake for the years 1948 to 1953 are shown in Table 8. Fingerling shad in Clearwater Lake grew faster than fingerling shad in the river. However, except in 1948, all other age groups made better growth in the river than in the lake. Shad of the lake population also had a longer life span. Six-year-old shad (members of the 1948 brood) were captured fairly commonly in gill nets set in 1954. In Black River only three captured shad were 5 years old. None were older.

Young-of-the-year shad serve as an important source of fish food for predacious fishes such as crappies and bass. They also compete in midsummer with the fisherman's lure; therefore the species is not a completely desirable component of the fish population.

TABLE 7.—*Percentage year-class composition of the catch of gizzard shad for 1½- and 1¾-inch mesh gill nets, 1949 to 1954.*

[Linen nets were used from 1949 to 1953. Nylon nets were used in 1953, also, and in 1954]

	1949	1950	1951	1952	1953	1954
1½-inch mesh gill nets:						
1948 year class	100	100	100	91	21	21
1949 year class	—	—	—	7	74	61
1950 year class	—	—	—	—	5	17
Total number fish	(37)	(33)	(86)	(70)	(794)	(358)
1¾-inch mesh gill nets:						
1948 year class	—	100	75	93	40	27
1949 year class	—	—	25	7	56	45
1950 year class	—	—	—	—	—	20
Total number fish	(0)	(4)	(15)	(15)	(25)	(82)

CATFISHES

Of the catfishes in Black River, the yellow bullhead was the dominant species. In two years of collecting on the river only one black bullhead and two channel catfish were captured. Despite this relatively small brood stock, black bullheads quickly became established in the new reservoir. In 1948 both black and yellow bullheads were netted in equal numbers but one year later black outnumbered yellow bullheads by more than 12 to 1 in the net catches. Very few adult yellow bullheads have been taken in the reservoir since 1948 although an abundance of fingerlings was noted in 1950 and 1953.

TABLE 8.—*Average calculated growth increments in inches in each calendar year for six age groups of gizzard shad in Clearwater Lake (1948-1953) and in Black River prior to 1948.*
[Number of fish in parentheses]

Age group	Calculated increment						
	1948	1949	1950	1951	1952	1953	River growth
0	6.4 (282)	6.0 (87)	6.4 (19)	6.0 (9)			5.0
I	4.9 (24)	2.1 (282)	2.5 (79)	3.4 (19)	5.5 (9)		4.0
II	2.8 (10)	1.4 (5)	1.3 (124)	1.3 (74)	1.2 (18)	0.9 (8)	3.0
III			1.2 (3)	0.9 (109)	1.0 (70)	1.0 (11)	2.2
IV				0.6 (2)	1.0 (35)	0.6 (36)	
V						0.6 (19)	

The estimated annual total hook and line catches of bullheads in Clearwater Lake, 1949 to 1954, were as follows: 3,100; 6,000; 14,100; 5,550; 10,225; and 4,250. Bullheads were not identified as to species in the creel census, but on the basis of net catches it is assumed that black bullheads predominated in angler's catches.

Few channel catfish appeared in the net catches or in the creels of sport fishermen until 1954 when they made up six percent of the net catch. Channel catfish of the 1952 brood (2-year-old fish) dominated the net catches in 1954 and ranged in length between 9.9 and 13.5 inches. Thus it took 5 years for this species to produce a successful year class. It is likely catfish will continue to be an important part of the fishery[7].

Flathead catfish are present but the population is believed to be small. No big hatches of young are known to have occurred in the lake.

CARP

The only carp taken in the pre-impoundment surveys of Black River were caught at a sampling station several miles below Clearwater Lake. Nevertheless a small population must have been present above the dam site since more than 100 fast-growing young-of-the-year carp, some as long as 12.5 inches, were gill-netted in mid-August of 1948 in the new lake. Carp of the 1951 year class dominated the net catches of 1952 and 1953, and the rotenone sample in 1954. Even though the net catches of adult carp have been small each year and few have entered the creel, the species probably has become well established in the reservoir. Forty hours of electric shocking in the spring of 1954 resulted in a catch that included 70 carp with an average weight of 5.9 pounds.

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[7] In 1955 more than 1,300 channel catfish were caught by anglers but in other years the estimated catch was less than 50 fish. In the fall of 1955 a Schnabel-type estimate of the channel catfish population was tried. After 5 weeks of test netting a population estimate of 6,769 channel catfish (7 inches long or longer) was computed. This was based on a five percent return of the fin-clipped fish. By the method of Schumacher and Eschmeyer (1943) an estimate of 4,962 channel catfish was calculated, with a standard error of 844.

FISHING PRESSURE, YIELD AND SUCCESS

The harvest of all game species, 1949-1954, is summarized in Table 9. Fishing pressure on Clearwater Lake has been light and the annual harvest likely well below the available harvestable crop.

TABLE 9.—*A 6-year summary of data on fishing pressure, yield, and success for Clearwater Lake (1949-1954).*

[Data for 1949 and 1950 are for the period May 30 to November 30 only, the then legal bass season. Data in part from Kathrein (1953)]

	1949	1950	1951	1952	1953	1954
Fishing hours per acre	44.1	60.1	111.2	79.0	87.4	88.4
Number of fish caught per acre	28.6	31.4	58.6	27.5	56.8	54.8
Pounds of fish caught per acre	6.8	10.4	31.3	15.2	25.7	22.1
Catch per hour	0.65	0.50	0.49	0.34	0.64	0.62

POPULATION DYNAMICS OF LARGER FISHES

Significant changes in the population of larger fishes in Clearwater Lake took place during the first 7 years of impoundment. The many variables that influence the establishment of a fish population in a new reservoir and were operative in Clearwater Lake were discussed by Martin and Campbell (1953). By 1954 the population had become fairly well stabilized, although short-term fluctuations may yet occur because of varying recruitment.

In 1954 the population samples of larger fishes were dominated, numerically, by gizzard shad, bluegills, longear sunfish, white crappie, bullheads, and golden redhorse. All of these fish are either prolific spawners, omnivorous feeders, or both. Longear sunfish, golden redhorse, and gizzard shad were abundant in the stream and provided a large breeding stock for the new reservoir. Although bluegills were a small part of the stream community they were one of the few fishes able to spawn in the reservoir as it filled in 1948. It is believed, too, that carp and channel catfish have become well established in the lake.

There are few predacious species in Clearwater. Smallmouth bass and rock bass, the two principal predacious fishes in Black River, were not able to increase in the reservoir. Walleye were also predators in the river but failed to become established in the lake. The largemouth bass is a primary predator in the lake but not numerous enough to have caused noticeable changes in the abundance of non-game species. White crappie have become well established although it took 3 years before this species produced a strong year class.

The failure of such species as smallmouth bass, rock bass, grass pickerel, hog sucker, and spotted sunfish to become established in the reservoir may be ascribed to lack of facilities for successful spawning or survival of the young. Their virtual absence from other Missouri impoundments is further evidence of their inability to adjust to reservoir conditions. It is presumed that a small brood stock was a limiting factor to population growth for some river fishes that failed to increase in the reservoir. These species include walleye, black buffalo, spotted sucker *(Minytrema melanops)*, northern carpsucker *(Carpiodes carpio)*, gar, flathead catfish, and sauger. Competition between closely related species may have restricted the numbers of black crappie, yellow bullheads, black redhorse, mooneye, and northern redhorse.

Most species capable of successful spawning in Clearwater Lake had produced one or more large broods by 1950. Channel catfish were slow to increase their numbers, presumably because of the small size of their brood-stock and the fact that they mature at a late age. In 1952 this species was successful in producing a large brood. Thus, by 1952, all species numerically important in the population in 1954 had produced at least one large crop in the reservoir. If successful spawning by all species of a population complex is accepted as a requirement for attaining carrying capacity, it can be assumed that the carrying capacity of Clearwater Lake was reached by 1952, or 5 years after the lake was impounded.

POPULATION DYNAMICS OF SMALL FISHES

The relative abundance of numerically important species of small fishes for the years 1952, 1953 and 1954 appears in Table 10, expressed as numbers captured per seine haul in mid-July at fixed sites. Four species, namely brook silversides, bluntnose minnows, bigeye shiners and whitetail shiners can be considered firmly established in the population since these were also the dominant species 1948-1950 (Martin and Campbell, 1953). The logperch has been found consistently in the reservoir, but in low numbers except in the 1954 collections. The studfish has been declining steadily in abundance each year. This species was abundant in Black River; in the reservoir it has been more common in the collections near the confluence of the streams and the reservoir. The common shiner did not appear in the lake collections 1948-1950, but since then there has been a slow build-up in numbers. Yearly fluctuations in relative abundance of any one species still occurred as late as 1954, but this is to be expected because of natural causes as shown by Moyle (1949) for long-established lake populations.

The observation that most of the small-fish population in the new reservoir consisted of fishes found formerly in the river backwaters (Martin and Campbell, 1953) still held in 1954. The four most abundant species (Table 10) were described as inhabitants of river pools (Martin and Campbell, 1953). Moreover, among the larger fishes, the abundant gizzard shad, bluegills, largemouth bass, white crappie and yellow bullhead were found formerly in the river backwaters. Species which were found in backwater areas or pools in the river, and which failed to increase in the lake included the redfin shiner *(Notropis umbratilis)*, blackspotted topminnow and golden shiner.

The continued occurrence of some species of small fishes in the reservoir is probably due to their movements from the river and tributary streams into the lake. This observation is supported by the presence of large numbers of these fishes in the seine hauls made near the inflows. These species included the stoneroller, bigeye chub, hornyhead chub, bleeding shiner, popeye shiner, and wedgespot shiner. Stonerollers were numerous in 1951 but few have been taken at other times in the lake other than near the headwaters of the three arms.

In summary, there were no large, persistent changes in the population of small fish in Clearwater Lake after 1950 so that the dominance of certain

TABLE 10.—*Relative numerical abundance of the principal small fishes in Clearwater Lake, 1952 to 1954, expressed as number per seine haul taken in July at fixed seining sites.*

Species	Number per seine haul		
	1952	1953	1954
Brook silversides (*Labidesthes sicculus*)	2.0[1]	2.1[1]	2.3[1]
Bluntnose minnow (*Pimephales notatus*)	0.2[1]	2.1[1]	2.4[1]
Bigeye shiner (*Notropis boops*)	2.2	4.5	10.2
Whitetail shiner (*Notropis galacturus*)	1.6	2.3	1.4
Logperch (*Percina caprodes*)	0.7	0.2[1]	3.6
Studfish (*Fundulus catenatus*)	..	0.6	0.2
Common shiner (*Notropis cornutus*)	..	0.1	0.7

[1] Only adults were counted. Young of the year were abundant in the seine hauls but were not enumerated. Other species of small fish captured included blackspotted topminnow *(Fundulus olivaceous)*, popeye shiner *(Notropis ariommus)*, bigeye chub *(Hybopsis amblops)*, wedgespot shiner *(Notropis greenei)*, bleeding shiner *(Notropis zonatus)*, golden shiner *(Notemigonus crysoleucas)*, streamline chub *(Erimystax dissimilis)*, hornyhead chub *(Hybopsis biguttatus)*, greenside darter *(Etheostoma blennoides)*, and mosquitofish *(Gambusia affinis)*.

species was established during the first 3 years of the reservoir's history. The population had stabilized by 1954, presumably near the carrying capacity of the reservoir, but minor changes in relative abundance will continue in response to environmental and ecological variations.

ACKNOWLEDGMENTS

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STUDIES ON RIVER-SPAWNING POPULATIONS OF LAKE TROUT IN EASTERN LAKE SUPERIOR

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ABSTRACT

Among the lake trout, *Salvelinus namaycush* (Walbaum), of eastern Lake Superior are some which, instead of spawning on reefs and shoals in the lake, enter certain rivers to spawn. Tagging and recovery studies were conducted on such fish seined from the Montreal and Dog rivers during the period 1951 through 1955. Male trout in Montreal River were found to mature at age 7 years when their average length was 25 inches. Females matured a year later when their average length was 28.5 inches. Trout in Dog River matured at the same ages but at lengths shorter by 3 to 4 inches, apparently because of slower growth during early life. Captures of the tagged trout in Lake Superior by sport and commercial fishermen showed that they frequented depths from 10 to 30 fathoms. Most of the trout recaptured were taken within 30 miles of the river in which they spawned. High recapture rates in the succeeding spawning season in the rivers at which they were tagged suggest that most of the trout return to the same river annually to spawn, and that the populations associated with each spawning run are discrete. The mortality rate of fish in the spawning run increased during the study period and reached an estimated 90 percent in both populations for the year 1954 to 1955. Spawning populations in both rivers declined from over 2,000 fish in 1952 to only a few fish in 1955. Catch of trout by sport and commercial fishermen was light, and was estimated to be less than 5 percent of the population each year. Incidence of scars caused by attacks of sea lamprey, *Petromyzon marinus,* greatly increased during the years when the trout population declined. It appears likely that the rapid decline of these populations of stream-spawning lake trout was caused by the increase of sea lampreys in Lake Superior.

INTRODUCTION

Tagging and recovery studies of some of the stream-spawning lake trout, *Salvelinus namaycush* (Walbaum), in eastern Lake Superior were initiated by the Sault Ste. Marie district staff of the Ontario Department of Lands and Forests in 1951 and were terminated in 1956 because of the decline in numbers of fish available for study, almost certainly brought about by sea lamprey predation. Sampling in 1956 took no trout.

Lake trout in eastern Lake Superior have scattered spawning grounds and diverse periods of spawning. Most of the spawning is on rocky bars and shoals, but there are a few spawning runs in streams. Most local commercial fishermen and hatchery personnel agree that the following areas in eastern Lake Superior are used for trout spawning and usually at about the dates listed.

Superior Shoal	July 4-30
Puckasaw River	September 5-15
Eagle River	September 12-20
Dog (University) River	September 17-30
Bear River	September 18-27
Gravel River	September 22-30
Montreal River	September 25-October 10
East Shore	October 15-November 20
North Shore (East of Puckasaw River)	October 26-November 6
Northwest Shore of Michipicoten Island	November 8-18
Southeast shore of Michipicoten Island	November 13-30

It is maintained by some, familiar with lake trout in the area, that other spawning locations and dates could be added to this list. Figures 1 and 2 show the locations of the spawning grounds listed, except for

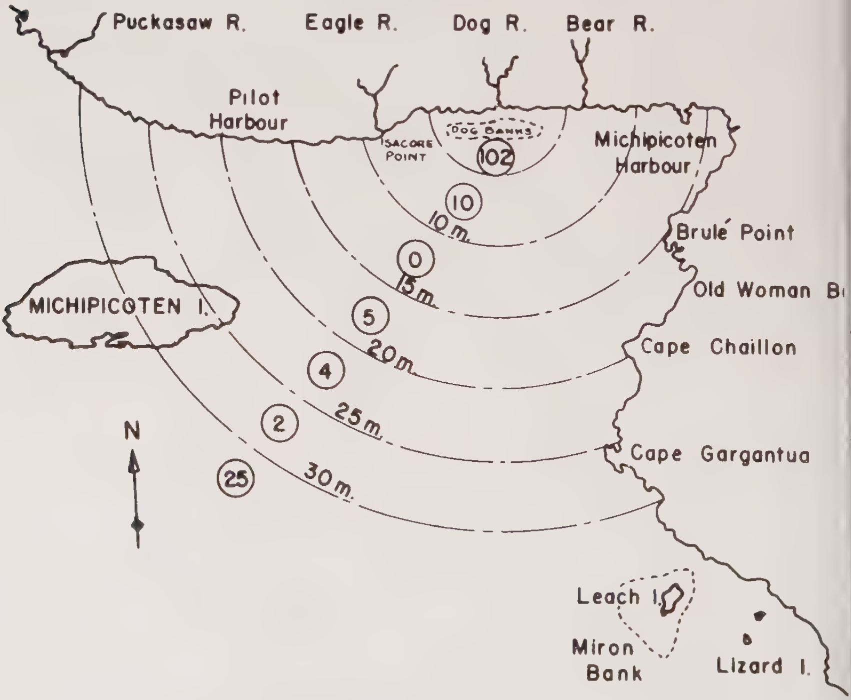
Puckasaw R.
Eagle R.
Dog R.
Bear R.
Pilot Harbour
Isacore Point
Dog Banks
102
Michipicoten Harbour
10
10 m.
Brulé Point
0
15 m.
Old Woman B
MICHIPICOTEN I.
5
20 m.
Cape Chaillon
4
25 m.
2
N
25
30 m.
Cape Gargantua
Leach I.
Miron Bank
Lizard I.

FIGURE 1.—Part of eastern Lake Superior adjacent to Montreal River, showing distances of fishing grounds from the river. Numerals in circles indicate number of tagged trout captured at these distances from the river.

Superior Shoal which lies further west. If the scattered spawning areas and differences in dates of spawning are attributes of a single trout population, their distribution and variation can be explained only on the basis of hydrographic data not yet available. At present they suggest the existence of more or less discrete groups or populations of lake trout within eastern Lake Superior. Most unusual among these spawning groups are those which enter the rivers, and even ascend rapids to reach spawning sites. The ease with which such trout can be captured during spawning makes them especially suitable for tagging and recovery studies.

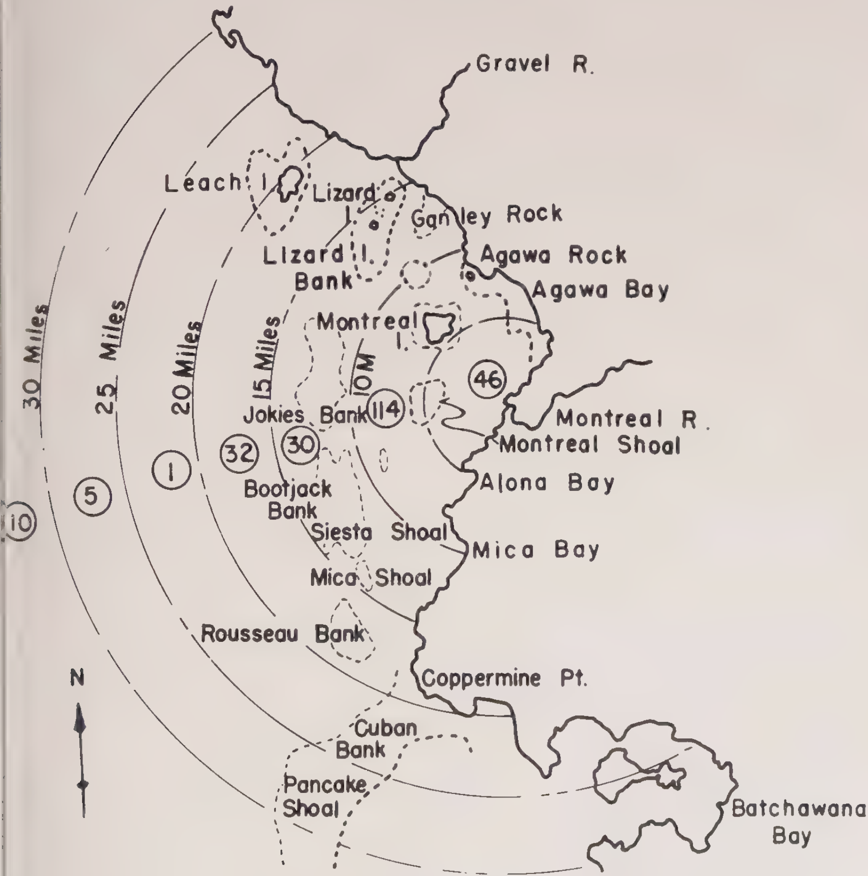
Gravel R.
Leach I.
Lizard I.
Ganley Rock
Lizard I. Bank
Agawa Rock
Agawa Bay
Montreal I.
30 Miles
25 Miles
20 Miles
15 Miles
10 M
46
114
Montreal R.
Jokies Bank
32
30
Montreal Shoal
1
5
10
Alona Bay
Bootjack Bank
Siesta Shoal
Mica Bay
Mica Shoal
Rousseau Bank
N
Coppermine Pt.
Cuban Bank
Pancake Shoal
Batchawana Bay

FIGURE 2.—Part of eastern Lake Superior adjacent to Dog River, showing distances of fishing grounds from the river. Numerals in circles indicate numbers of tagged trout captured at these distances from the river.

METHODS

Trout were captured at night in a 300 foot seine which was 20 feet deep at the middle and tapered to a 5-foot depth at the ends. The seine was set in an arc from one shore just inside the river mouth, being payed out from the back of a punt. As many as 1,000 trout have been caught in a single seine haul. The trout were held by the seine at the edge of the river while hatchery and tagging personnel performed their respective tasks.

To facilitate handling, the captured trout were anaesthetized until they became sluggish in a tank containing an approximately 5 percent urethane solution. Fork length, to the nearest half inch, sex, and lamprey scarring data were recorded; scale samples were taken; and oval plastic tags were affixed at the anterior basal part of the dorsal fin with mono-filament nylon. During 1952 and 1953, fins were clipped to determine the extent of tag loss. Subsequent recovery of fin-clipped trout without tags indicated that about 10 percent of the tags were lost the first year. This is similar to the tag loss reported by Fry (1953) for the same tagging method. Data collected from recaptured trout included length, sex, lamprey scarring, and scale samples. Later, impressions of scales in cellulose acetate strips were made to facilitate aging of the fish.

Returns of tags and information about lake trout caught by sport and commercial fishermen was on a voluntary basis. Therefore data obtained provided only minimal estimates of population exploitation, but were adequate for interpretation of the distribution of the populations in the lake.

Tagging studies were initiated at Montreal River in 1951 and at Dog River in 1952 and were continued annually through 1956. Some tagging was also done at Eagle River in 1954 and at Puckasaw River in 1954 and 1955. Table 1 shows the numbers of trout tagged each year and the total for each river. In 1951 only a fraction of the trout captured were tagged but all unmarked trout caught in subsequent seasons were tagged, with

TABLE 1.—*Numbers of lake trout tagged in Ontario rivers tributary to eastern Lak Superior in the years 1951 through 1955.*

Year	Locality			
	Montreal River	Dog River	Eagle River	Puckasaw River
1951	920			
1952	763	556		
1953	405	1203		
1954	200	401	49	40
1955	0	13	0	11
Totals	2288	2173	49	51

the exception of six trout caught over an extended period at Montreal River in 1955. During the entire study, 4,561 lake trout were tagged.

MONTREAL RIVER SPAWNING RUN

Montreal River enters eastern Lake Superior at a point 80 miles by road north of Sault Ste. Marie. Lake trout are reported to have been spawning in this river for many years and may have been more abundant in earlier years than shown by investigation since 1949. Trout first enter the river and appear over the spawning grounds usually soon after September 24. The peak of spawning activity occurs about a week after the beginning of the run, and few trout enter the river after October 10. However, in years when the run starts late in the season, the peak of spawning activity seems to be reached more rapidly so that the duration of the run is shortened. Some trout can be caught in the river at all times of the day, but it is characteristic for them to move into the river from the lake and out again during darkness. They begin moving in shortly after dark and soon are present in peak numbers. It is difficult to say when individual fish begin to leave the spawning grounds, but by midnight, most of them have returned to the lake where they remain in the deep water off the river mouth until the next evening. Severe storms accompanied by on-shore winds tend to close the river mouth with shifting sand and gravel. This sometimes causes unusual numbers of trout to remain in the river during the day. Characteristic of the annual spawning, and to some extent of the daily spawning activity, is the predominance of males in the early and late parts of the run. The sex ratio approaches 1:1 during the peak of activity.

The spawning bed at Montreal River consists of large boulders intermixed with coarse gravel in an eddy near the lower end of a gorge some 200 yards from Lake Superior. The chief predator on eggs is the menominee, *Prosopium cylindaceum*, large numbers of which appear with the lake trout and remain in the river throughout the spawning period. Stomachs of menominees examined contained as many as 150 lake trout eggs.

Eggs, stripped from these lake trout and incubated at the Huron Street Hatchery in Sault Ste. Marie, have hatched as early as late November. Since water temperatures at the hatchery and in Montreal River are similar, hatching probably occurs at about the same time in the river.

DOG RIVER SPAWNING RUN

Dog River flows into eastern Lake Superior at a point 15 miles west of Michipicoten Harbour. Although reports of a spawning population in this stream date back several years, remoteness of the area is such that few valid statements on its history are available. It was found that lake trout begin entering Dog River to spawn on September 15 to 17. After October 1, few trout remain in the river. Characteristics of this spawning run were similar to those of lake trout spawning at the Montreal River. Deep water in the lagoon just inside the river mouth apparently provides sufficient cover for trout during the daylight hours. During the 1953 spawning period, trout habitually remained in this pool during the day and because of this habit these trout were more available to the seine. Severe storms in 1954 completely closed the river mouth for a few hours, isolating some trout in the river and preventing others from entering it.

The extensive spawning bed used by these trout is almost two miles upstream at the base of a 40-foot falls. To reach this area the trout make their way over several steep rapids. Menominees were present in large numbers during the spawning.

PUCKASAW AND EAGLE RIVER SPAWNING RUNS

In 1954 the work was expanded to include observations on the spawning runs in Eagle and Puckasaw rivers. These rivers enter northeastern Lake Superior at distances of approximately 25 and 70 miles respectively west of Michipicoten Harbour. Although only a few trout were tagged, the existence of the spawning runs was confirmed.

At the Eagle river, which is only about 12 feet wide, the lake trout ascend a small rapids at the shore of Lake Superior, pass through a 50-foot pool and spawn at the foot of a second rapids. None of the 50 lake trout which were caught and tagged in 1954 bore tags from either Montreal or Dog rivers.

The Puckasaw River is similar in size to Montreal and Dog rivers and like them enters the lake around the end of a wave-deposited bar which varies in size depending upon wind conditions. In 1954 and 1955 the mouth was about 40 feet wide. Lake trout spawn on typical grounds below a 30 foot waterfall one-half mile upstream. As at Dog River the trout ascend steep rapids to reach the spawning site. Seine hauls in 1954 and 1955 captured only 62 trout. One trout bearing a green tag, presumably from Dog River, was seen in a pool during 1954.

AGE COMPOSITION OF SPAWNING POPULATIONS

The age composition of the Montreal River spawning populations in 1951 and 1952, and of the Dog River spawning population, is shown in Figure 3. Scales from 1496 lake trout from Montreal River and 550 from Dog River were read.

In Montreal River in 1951, and in Dog River in 1952, trout of four age groups: VIII, IX, X and XI, were abundant in the population. Trout of group X were more abundant than trout of any other age. The Montreal River population in 1952 consisted largely of trout a year older than those taken in 1951. In 1952 trout of age group XI were the most abundant, and the numbers of trout of age groups VII and VIII were smaller than

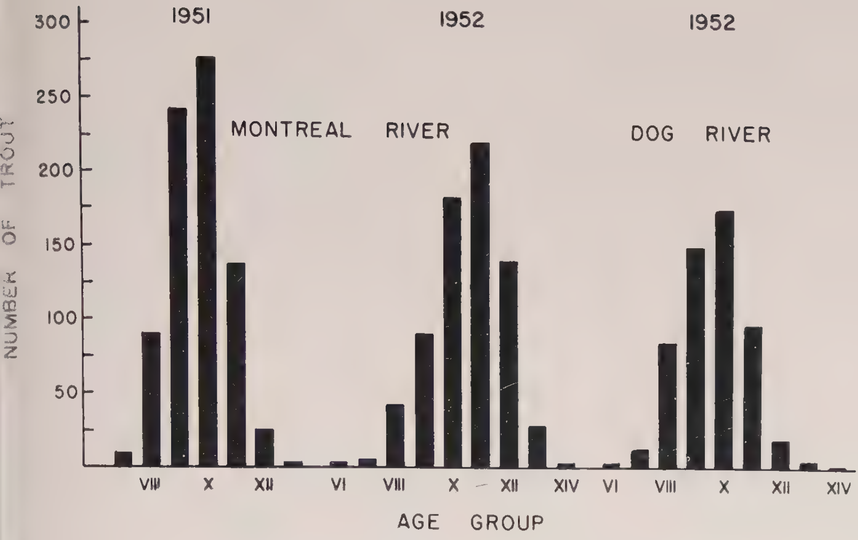

FIGURE 3.—Age composition of spawning lake trout at Montreal River in 1951 and 1952, and at Dog River in 1952.

might have been expected. The age composition of the spawning populations in the years 1953, 1954 and 1955 have not been determined at this time.

AGE AND SIZE OF TROUT AT SEXUAL MATURITY

The youngest mature lake trout taken in the spawning runs were one 6-year old male from each river. Many males and a few females were found to be mature at seven years. Most of the females appeared to be mature at eight years of age.

Mean fork lengths of the age groups of lake trout from Montreal River and Dog River in 1952 are shown in Figure 4. It will be observed that trout from Dog River were smaller at maturity than those from Montreal River. Growth rate for trout in Montreal River decreased after nine years of age when the average size was about 30 inches. Continued rapid growth appeared to be maintained by Dog River trout at least one year longer than by trout in Montreal River. The average lengths of Dog River trout for the ages represented in the spawning run were three to four inches less than lengths of Montreal River trout of corresponding ages.

If it is assumed that the smallest individuals in these spawning populations represent minimum size at maturity, the first males to mature in Montreal River were about 23 inches long and most males were mature at seven years of age when their average fork length was somewhat more than 25 inches. Some female trout also matured at this length and age, but

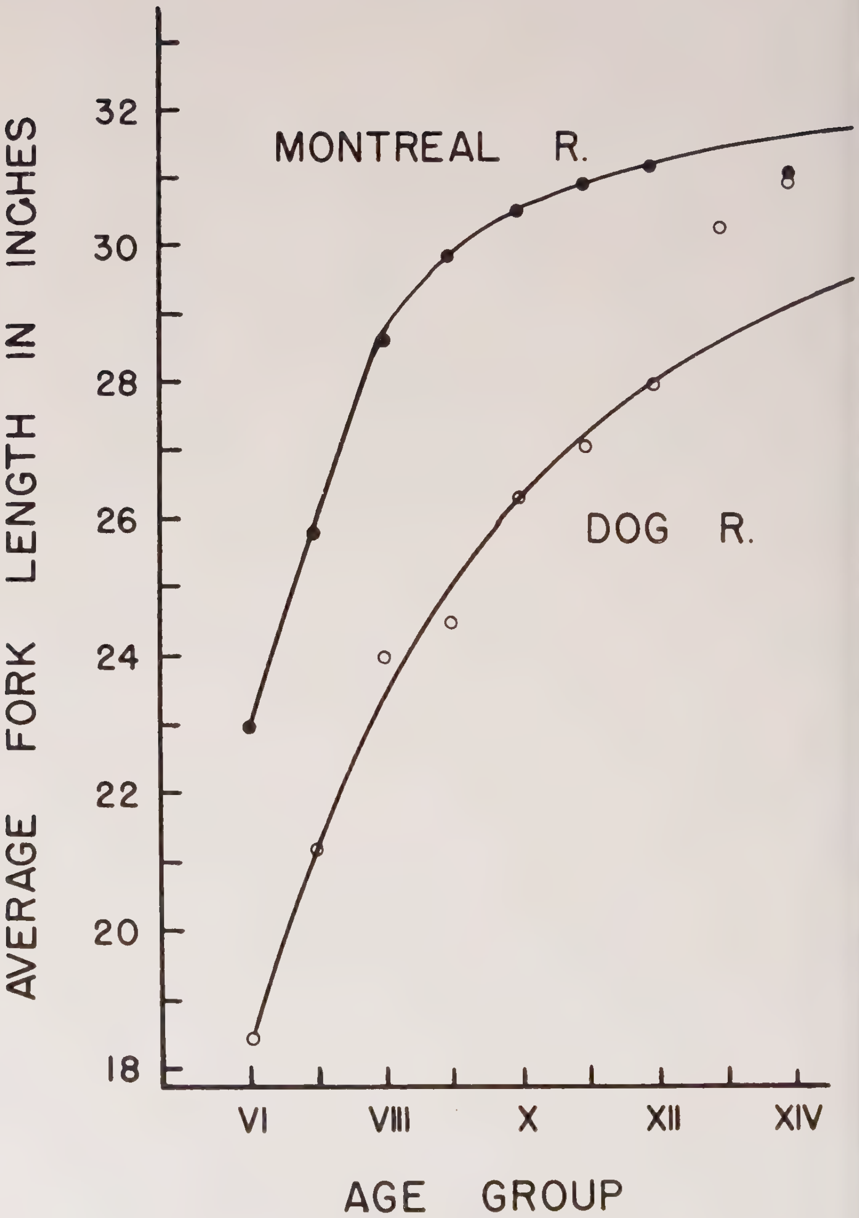

FIGURE 4.—Comparison of mean fork lengths of trout at ages represented in the spawning populations in Montreal and Dog Rivers.

most were eight years old at maturity when their average length was about 28.5 inches. These data are in agreement with the findings of Eschmeyer (1955) for trout in southern Lake Superior.

In Dog River the lake trout matured at the same ages as in Montreal River, but both sexes were three to four inches shorter than were Montreal River trout at maturity. Males matured in Dog River at an average length of 21 inches and females at about 24 inches.

Length-frequency distributions of trout from Montreal River for the years 1951-1954 are shown in Figure 5. Even if allowance is made for unevenness of seining effort, there is a marked population decline and the greatest proportionate decline is in the older age classes. The trout in the 1951 population apparently were not replaced as they disappeared from the run in the years following 1951. Interpretation of the data for Dog River trout as shown in Figure 5 was made difficult by the change and improvement of sampling methods in 1953. A severe decline in the population was evident in 1954 however. Too few trout were obtained in 1955 at both rivers for adequate length-frequency data.

The sex ratio for 833 of the lake trout examined at Montreal River in 1951 was one female to 2.4 males. In 1952, 1953 and 1954 when sex data for 645, 403 and 181 lake trout respectively were recorded, the sex ratios were 1:1.1 in 1952, 1:1.7 in 1953, and 1:3.5 in 1954. The pronounced trend towards an increasing proportion of males in this population after 1952 was also evident in the Dog River population where the ratio of females to males was 1:0.8 in 1952, 1:1.2 in 1953, and 1:2.2 in 1954, as shown by sex data recorded for a total of 2243 trout.

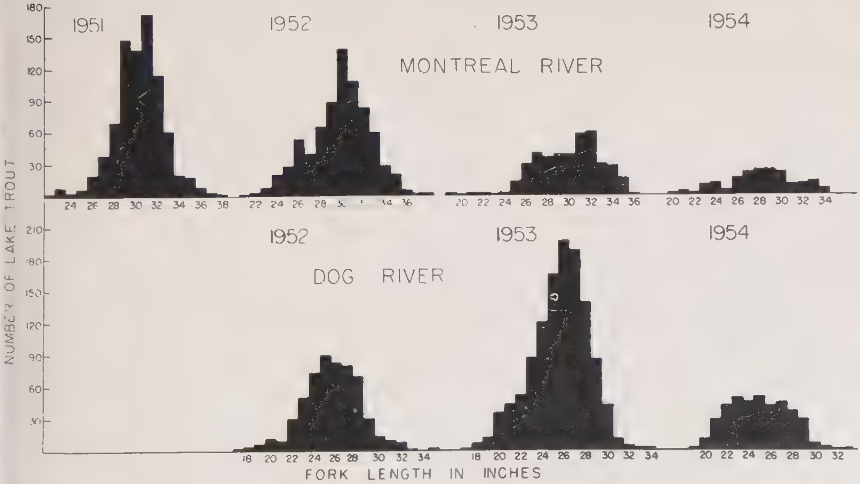

FIGURE 5.—Length-frequency composition of the spawning populations at Montreal River in 1951, and at Montreal and Dog Rivers in 1952, 1953, and 1954.

RECAPTURE DATA

Data on recapture of tagged trout come from three sources: (1) tags on fish taken in seining on the rivers during seasons subsequent to 1951; (2) tags returned by commercial fishermen; (3) tags returned by sport fishermen. Tagged trout taken in our seine at the rivers are termed "river recaptures" and were returned to the river after being examined. Tagged trout taken by sport and commercial fishermen were removed from the population and are termed "caught". The numbers of trout known to have been taken by anglers were small and in most instances the angling and commercial catch are combined in subsequent discussion.

RIVER RECAPTURES

The large number of river recaptures suggests that a large part of the population returns to spawn on the same grounds each year. Handling of the trout during tagging, measuring and inspection apparently did not discourage their repeated return to the same grounds during any spawning season. Some trout were recaptured in late night seine hauls after having been tagged earlier in the evening and many were recaptured the night following the one when they were tagged. Recaptures also showed that a trout might enter the river with the run several nights before spawning, and occasionally might enter after spawning had been completed. One female trout, "hard" when tagged on September 26, 1952, was spawned artificially eleven days later when recaptured on October 7. Another, tagged on September 25, 1952, was still not ready to spawn when recaptured 10 nights later. Females that were "hard" when tagged usually were ready to spawn 3 or 4 nights later.

Numbers of lake trout recaptured each year from the Montreal and Dog Rivers are recorded in Tables 2 and 3. Multiple recaptures of the same fish are also listed. These data are complete except for 1951, the first season of operation, when recaptures were not recorded, and for 1955 when very few fish were available from normal seining efforts.

Of the 920 lake trout tagged at Montreal River in 1951, 364 individuals or 33 percent were recaptured from the river in the three subsequent seasons. Some trout were recaptured as many as five times in a single season and many individuals were taken in three subsequent seasons. A total of 711 recaptures were recorded for trout tagged in 1951. In 1952, 763 more trout were tagged and during that season and the two following spawning seasons 283 individual or 37 percent were recaptured at least once. Of these recaptures, 135 individuals were taken during the season when they were tagged. Ninety, or 22 percent, of the 405 trout tagged in 1953 were recaptured in 1953 and 1954. Fourteen percent of the 200 trout tagged in 1954 were recaptured during the operation of that season.

At Dog River 42 percent of the 556 trout tagged in 1952 were recaptured at least once in that and the two following spawning seasons. Including multiple recaptures of the same trout, the total number of recaptures was 426. Of 1203 trout tagged in 1953, 388 individuals or 32 percent were recaptured in 1953 and 1954, and including multiples the total number of recaptures was 515. The total number of recaptures of the 401 trout tagged in 1954 was 74. None of the 13 trout tagged in 1955 has been recaptured.

As has been noted, many lake trout were retaken at the site of their tagging for two successive seasons, several were caught at their tagging

TABLE 2.—*Number of lake trout tagged at Montreal River in 1951, 1952, 1953, and 1954, recaptured at Montreal River in each year of the study.* [The total number of recaptures, the number of trout not previously recaptured and the numbers of trout recaptured more than once are included for each year.]

Year recaptured	Total number of recaptures	New individuals recaptured	Individuals recaptured			
			Two times	Three times	Four times	Five times
Trout tagged in 1951—920						
1951						
1952	385	275	89	18	2	1
1953	269	87	63	25	4	0
1954	57	2	14	5	0	0
Totals	711	364	166	48	6	1
Trout tagged in 1952—763						
1952	161	135	24	2	0	0
1953	267	134	62	21	5	1
1954	39	14	5	1	1	0
Totals	467	283	91	24	6	1
Trout tagged in 1953—405						
1953	90	74	13	3	0	0
1954	56	16	11	0	0	0
Totals	146	90	24	3	0	0
Trout tagged in 1954—200						
1954	31	28	3	0	0	0

sites for three successive seasons and some for four. Of the 920 trout tagged at Montreal River in 1951, 275, 29 percent, were recaptured there in 1952 and of these 203, 74 percent were males. Of all 2088 trout tagged at Montreal River in 1951, 1952 and 1953, 86 or just over 4 percent were recaptured three years in succession and 76 of these, about 88 percent, were males. Sixteen males, but no females, returned and were recaptured in four successive seasons. Of 556 trout taggd at Dog River in 1952, 163 individuals, 29 percent, were recaptured there in 1953. Two-thirds of these were males. Twenty-seven of these trout, 23 males and 4 females, were taken from the river in three successive seasons. Even after making allowance for the previously noted shift to malesness in the sex ratio of the

TABLE 3.—*Numbers of lake trout tagged at Dog River in 1952, 1953, 1954, and 1955, recaptured at Dog River in each year of study.* [The total number of recaptures, the number of trout not previously recaptured and the numbers of trout recaptured more than once are included for each year]

Year recaptured	Total number of recaptures	New individuals recaptured	Individuals recaptured			
			Two times	Three times	Four times	Five times
Trout tagged in 1952—556						
1952	121	96	19	5	1	0
1953	245	129	56	20	3	1
1954	60	11	11	2	0	0
Totals	426	236	86	27	4	1
Trout tagged in 1953—1203						
1953	325	274	44	6	1	0
1954	189	113	35	7	1	0
1955	1	1	0	0	0	0
Totals	515	388	79	13	2	0
Trout tagged in 1954—401						
1954	71	60	8	1	1	1
1955	3	3	0	0	0	0
Totals	74	63	8	1	1	1
Trout tagged in 1955—13						
1955	0	0	0	0	0	0

spawning populations after 1952, these data suggest that females as well as males spawn annually on the same grounds, but that female lake trout are either subject to higher mortality than the males or, less likely, are less constant than the males in choice of a spawning site.

SIZE OF POPULATIONS

It became obvious at an early stage of the study that the populations of stream-spawning trout were quite small. With substantial numbers of trout tagged and evidently substantial proportions of the adult fish in the populations tagged, one would have expected an estimate of population size to be fairly easy. However behaviour of the fish and sampling uncertainties made estimates difficult. The numbers of trout captured in the early and late parts of the run were small as compared to the numbers at the peak of the run. Some individuals apparently stayed with the spawners all through the run while others spawned early and left the river. In our efforts to catch as many trout as possible the seining site was often shifted up or down river or from one side to the other. Thus our sampling of the population was not consistent in respect to location. Nor was it consistent with respect to time, except in some measure by the clock. A seine hauled early, in relation to the nightly run, usually caught few trout, but at times such a haul occupied the crew until after the nightly peak of the run had passed the seining site. Hauling the seine and the activity of the crew in tagging and stripping the trout seemed to frighten the trout so that they moved in along the opposite river bank. Paloheimo (1954) discusses some of these difficulties. He estimated the Montreal River population to be between 2067 and 2833 fish in 1952 and between 1234 and 1632 fish in 1953. The data for 1954 and 1955, which were not available to Paloheimo when he prepared his report, indicate clearly a further decrease in population size. In 1954, 200 trout without tags, and 116 tagged trout were caught. In 1953, when Paloheimo estimated the population at 1200 to 1600 trout, a total of 750 trout or approximately half of the estimated total population were handled. Assuming that half of the total population was also handled in 1954, the total population estimate for that year would be 600 trout. Similarly, the population in 1955 must have been fewer than 50 fish. Although a similar estimate of the 1951 population cannot be made because the total number of individuals handled was not recorded, it is considered that the population in that year probably approached 3000 trout. Decrease in the number of fish in the spawning run is estimated at about 20 perecent between 1951 and 1952; 42 percent between 1952 and 1953; 57 percent between 1953 and 1954 and 91 percent between 1954 and 1955.

Paloheimo (1954) estimated that the Dog River spawning population contained between 1270 and 1561 lake trout in 1952 and between 1670 and 2319 in 1953. During the operations at Dog River in 1952 the same sampling technique was used as had been used at the Montreal River, that was, seining only at night. In 1953, it was discovered that these trout tended to remain within the river during the day. By seining both during the day and the night, the numbers of trout captured and tagged in 1953 was much higher than the number taken in 1952 and it is considered therefore that a larger proportion of the population was taken in 1953. In that year about 1600 individual lake trout were handled, or about four fifths of the estimated total population for that year. In 1954 methods of sampling were consistent with those used in 1953, and assuming that again four fifths of the population were handled in recording 655 individual trout, then the population may be estimated at approximately 820 trout. Similarly the population at Dog River in 1955 must have been fewer than 50 trout.

Populations at both rivers were small, consisting of less than 3000 trout and each suffered mortalities that resulted in the virtual disappearance of the run during the period of the study.

RECAPTURES BY SPORT AND COMMERCIAL FISHERIES

Contrary to local opinion commercial fishermen, rather than anglers, took most of the fish removed from these populations by fishing. The combined exploitation, however, was surprisingly light. Table 4 sum-

TABLE 4.—*Recaptures by years of trout tagged at Montreal and Dog Rivers by commercial fishermen (C) and anglers (A).*

Year tagged	Year recaptured										Totals	
	1951		1952		1953		1954		1955			
	C	A	C	A	C	A	C	A	C	A	C	A
Montreal River												
1951.......	14	2	34	2	44	4	12	0	2	0	106	8
1952.......			23	1	58	5	17	0	1	0	99	6
1953.......					2	1	27	0	3	0	32	1
1954.......							4	0	3	0	7	0
Totals.....	14	2	57	3	104	10	60	0	9	0	244	15
Dog River												
1952.......			12	0	17	5	25	1	0	0	54	6
1953.......					15	3	69	7	1	0	85	10
1954.......							0	0	3	0	3	0
1955.......									0	0	0	0
Totals.....			12	0	32	8	94	8	4	0	142	16

marizes the data on the number of tagged trout captured by commercial fishermen and anglers each year.

Of all trout tagged at Montreal River during the study, 259 were reported caught and of these only 15 by anglers. Thus, of the estimated population of 3000 fish in 1951, about 9 percent were reported captured from 1951 through 1955 and only half of one percent were reported by anglers. This amounted to an average of less than 3 percent per year reported captured, and even if it were assumed that only half of the captured fish were reported, an overly pessimistic assumption, the expoitation was still light.

Of trout tagged at Dog River, 158 were reported captured. Anglers reported 16 of these, 10 percent, and evidently fished this population more intensively than they did the Montreal River population. Paloheimo estimated the Dog River population at 1400 in 1952 and at 2000 in 1953, as has been noted. Since it is likely that the population in 1952 was in inadequately sampled, it is estimated the population contained at least 2000 fish in that year. If this is so, then during the next three years of the study about 8 percent of the population was utilized by commercial and sport fishermen. This utilization is in the order of two or three percent of the population each year. In those same years, mortality of fish in the spawning run increased to 90 percent.

In Table 5 data for tagged trout taken by fishing and for river recaptures are combined to show total percentage return of tagged fish for each year of tagging. Since no weighting for tag loss has been included, the true percentages are presumably higher than those listed. Had river recaptures been recorded in 1951, the total percentage return for 1951 tags from Montreal River would probably have been in the order of 65 percent.

DISTRIBUTION OF CAPTURES

Commercial fishermen, fishing at all depths up to 80 fathoms, reported capturing all tagged trout at depths from 5 to 30 fathoms. It appeared,

TABLE 5.—*The total percentage return of trout tagged at Montreal River in 1951, and for trout tagged each year thereafter at Montreal and Dog Rivers.*

Year tagged	Total percentage return	
	Montreal River	Dog River
1951	50	
1952	51	53
1953	30	40
1954	17	17
1955		0

therefore, that river-spawning trout remain in relatively shallow water all year.

Numbers of trout reported captured within radius intervals of 5 miles up to 30 miles are shown in Figure 1 for Montreal River trout and Figure 2 for Dog River trout. These figures also give the location of the grounds on which most of the captures were made. The Montreal River trout, after leaving the river, apparently distributed themselves to all shoals within 30 miles of the river. Some 4 percent of the trout went beyond the 30 mile radius to Michipicoten Island, Clay Banks, Dog Bank, Caribou Shoal and Michipicoten Harbor, locations up to 70 miles distant from the Montreal River. One apparently valid but surprising recapture was reported from the south end of Lake Michigan, over 400 miles from the river.

Two clearly defined movements are shown by reported captures of trout from Dog River: the move to near-by Dog Bank, and a westward movement along the north shore of Lake Superior. Thus 102 capture reports were received from the immediate vicinity of Dog River and Dog Bank, and in the westward movement reports were as follows: 2 from Eagle River, 8 at Isacore Point, 4 at Pilot Harbour, 1 at Simmons Harbour and 14 off Puckasaw River. Further west and north, single captures were reported from Steele River, Prairie River, Pic Island, Copper Island Point and Isle Royale. Reports of captures at Michipicoten Island, Clay Banks, Montreal Island, Miron Bank, Beaver Rock and Michipicoten Harbour confirmed mixing of this population with Montreal River trout in the lake.

During the spawning periods only a very few tagged trout were captured by commercial fishermen, and those very close to the home rivers. Captures were numerous both before and after the spawning run and number of captures at other seasons appear to be related primarily to the intensity of the commercial fishing effort.

DISCRETENESS OF POPULATIONS

Evidence given permits the conclusion that the trout populations spawning in Montreal River and in Dog River are distinct groups which separate at spawning time, not only from each other, but probably from other lake trout in Lake Superior. Many trout tagged at Montreal River returned to that river in successive seasons to spawn but none of these trout was ever taken on Dog River spawning grounds. Conversely no trout tagged at Dog River was ever captured at Montreal River. This separation for spawning occurred despite evidence indicating a limited mixing of the two populations in the lake. It is obvious from commercial catch records that these trout mingled with other lake trout during most of the year. Although it cannot be demonstrated with certainty that all of the spawning trout of the river runs spawned only in their home river and none of them spawned on shoals in the lake, yet return to home streams for spawning is strongly indicated by scarcity of marked trout in the catch from the lake during the spawning period and by the increased catch of such fish near the river immediately before and after the river run.

SEA LAMPREY SCARRING DATA

Table 6 summarizes data on extent of sea lamprey scarring on the lake trout of both spawning populations. Incidence of scars on trout captured at Montreal River in 1951 was not recorded, but it is likely that there were few. The percentage of scarred fish increased rapidly from 2.9 percent in 1952 to 22.9 percent in 1954. No data were recorded for the six trout captured at Montreal River in 1955. Incidence of scarring was consistently higher each year for the Dog River trout than for Montreal River trout. At Dog River the percentage of scarred trout rose from 3.9 in 1952 to 33.4 in 1954. Although 19 trout captured at Dog River in 1955 may be considered a very small sample, a considerable amount of effort was required to take them and in this sample 84 percent of the fish bore lamprey scars.

TABLE 6.—*Occurrence of fresh and healed sea lamprey scars on lake trout at Montreal and Dog Rivers.*

Year	Number of trout examined	Number with fresh scars	Number with old scars	Percent scarred
Montreal River—September-October				
1952	1313			2.9
1953	952	38	54	9.7
1954	362	50	33	22.9
1955	6			
Dog River—September				
1952	556			3.9
1953	1367	35	123	11.5
1954	732	24	221	33.4
1955	19	5	11	84.0

During the last three years of the study, live lampreys were frequently seen attached to the trout in the seine. At Dog River in 1955 when only 19 lake trout were taken, 2 live lampreys were caught and destroyed. There is little doubt but that the rapid increase in the incidence of lamprey scars during the course of the study was a reflection of an increase in the population size of the recently introduced sea lamprey. There is ample evidence from other areas in and around Lake Superior that the numbers of sea lampreys increased during these years of trout population decline in Montreal and Dog rivers. Likewise it is highly probable that the increased mortality suffered by these populations during the years of the study was caused by sea lamprey predation. During each year of the study a large part of the total population of these streams was examined and no evidence of disease or parasites other than the sea lamprey, was encountered. Water levels were low and stream temperatures were higher than usual in 1954 and 1955 and this possibly may have influenced the run. However, in these years some trout did return to the rivers and the associated menominees arrived in force. Commercial fishermen in these years found poor spawning populations on many grounds in the lake but nowhere did they find an unusual concentration of tagged trout from the river runs.

Age and length-frequency compositions of the populations suggested strongly near failure of recruitment to the spawning population during the study. Fry (1953) demonstrated that when sea lampreys were present, lake trout populations were vulnerable to attack after ages four and five and that few trout in the South Bay population survived to maturity. At both Montreal and Dog Rivers the sex ratio shifted strongly towards males after 1952, while females and males were being equally exploited by commercial fishermen. This may demonstrate that mature female trout are more vulnerable to sea lamprey attack than males, perhaps because of the larger size and greater age and possibly because of a lowered vitality after spawning.

Total mortality among these spawning populations was high, estimated to be about 90 percent between 1954 and 1955. Exploitation by commercial fishermen and anglers was light, being in the order of two to five percent. These considerations, together with the evidence indicating increased numbers of sea lampreys and increase in lamprey scarring on trout, leave little doubt that, as Hile, Eschmeyer, and Lunger (1951) concluded for lake trout in Lake Michigan, the sea lamprey was the cause of the decline of lake trout. Fearing that these interesting stream spawning populations might be exterminated by the sea lamprey in a short time, all young trout reared from eggs collected at the rivers in 1955 are being retained. With these it is hoped that the populations may be re-established after the sea lamprey has been controlled.

ACKNOWLEDGMENTS

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Part 2

Symposium
on
Commercial Fisheries

[Future Crisis in Commercial Fishing Production]

SYMPOSIUM ON COMMERCIAL FISHERIES
INTRODUCTION

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The maintenance of stocks of fish on which our present commercial fisheries rely is of utmost concern to those whose living depends upon the utilization of these great resources. Almost equally concerned are the fishery scientists who labor patiently and diligently to maintain maximum yields in the older fisheries and to develop new resources to assure a future supply. For years, often these resources have been taken too much for granted, and now with increasing human population we are faced with the possibility that during the next 20 years the demand for fishery products will outrun our production unless new fisheries are located and developed.

Until 1950 the catch of food fish in the United States generally paralleled our population growth. Since 1950 our production of food fish has dropped one-fifth while our population has grown one-fifth. The gap has been filled from other sources outside the United States. It is likely that production of our domestic fisheries could have been greater under incentive of better prices, but probably not enough to meet our total needs. While our catch of food fish has declined, the catch of species used for industrial purposes has increased sufficiently so that the total catch has risen slightly. Even this increase in total catch is not in proportion to our population increase.

Looking toward the future the Bureau of Census estimates that the population of the United States will increase 30 percent to a total of 221 million by 1975. At our present per capita consumption of fish it would require a catch increase of 1.5 billion pounds of fish to fill United States needs alone in 1975.

Many of the older fisheries in North America have become mature in that increases in the amount of fishing, or extension of the fishing area will not permanently increase yield. We must not only make the most of our traditional fishery resources but must supplement them by developing new ones. A considerable amount of exploratory and developmental work has been done, but if we are to meet future needs more such work is needed.

CONTRIBUTION OF BIOLOGY AND OCEANOGRAPHY TO INCREASED HARVEST OF MARINE FISHES[1]

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Abstract

Management of marine fisheries, when compared to agriculture, is handicapped by the small amount of influence that can be exerted in any phase of fish production except the harvest. However, fishery science can contribute to increased fish catches in several ways. Although planting of hatchery-reared marine fish has been of little use, cultivation of marine animals, particularly of molluscs, can produce increased quantities of seafood. There is a possibility of inducing artificial up-wellings of more fertile bottom waters. Scientific investigations can help avoid artificial and unnecessary limitations which restrict efficient fishing operation. Research can also point out ways to avoid waste of fish and fishing effort which results from depletion of heavily exploited stocks. Predictions of availability and of abundance and correlation of such predictions with hydrographic conditions can assist fishing operations. Studies in fish behavior and reactions under given circumstances can aid in the design and operation of fishing gear.

Introduction

Science has contributed much more to the progress and welfare of farmers than to that of the fisherman. There are several important reasons for this that are worthy of detailed consideration.

First, the ocean fishery resources are owned by everyone and therefore by no one. And it is an unusual individual who will treat something he owns in common with the rest of the community or nation with the same care that he treats his individually owned property. A farmer will cheerfully accept suggestions concerning his own land from an agricultural research laboratory, even though some of the suggestions may temporarily reduce his yields. But the fisherman is loath to follow the advice of the fishery scientist because someone else may be reaping the crop if he leaves his gear idle. Because many fisheries are international, complexity is compounded and the fishery scientist may be faced with the prodigious problem of presenting his recommendations to a group of nations and convincing all that they should be adopted.

Secondly, the information on which the fisheries scientist can base his arguments is usually more scanty and less certain than that of the agricultural scientist because of the tremendous complexity of marine science. Fishermen lack most of the control over their resources that is available to farmers. They cannot control the amount of seed; they cannot control nor improve the conditions of growth of the young crop; they usually cannot control the pests, predators or diseases of their stock; they cannot count the animals they will harvest nor cull out the inferior ones; they cannot pen their stock so they are easily available for harvest, and often, they cannot carry out the harvest in a planned and efficient manner. Science, especially fishery biology and oceanography, can often help the fisherman only in the final phase of the productive cycle by suggesting ways for increasing harvesting efficiency. But even here science is helpless without the cooperation of the fisherman and fishing industry.

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Following are the more important ways in which biology and oceanography can influence the production of marine fisheries:

1. By hatching or cultivation of marine organisms when prospects are favorable
2. By control or encouragement of fishing effort, through recommendations for regulations, where they are necessary, and the avoidance of such recommendations where no controls are required
3. By determination of relationships between hydrographic conditions and fish distribution and abundance.
4. By the elucidation of patterns of fish behavior
5. By the prediction of the yearly abundance of fish available to the fishery.

HATCHING OR CULTIVATION OF MARINE ORGANISMS

Marine fish hatcheries have been notably unsuccessful in influencing the amount of seafood produced, and the "magic wand of protected cultivation" which Bower (1898) suggested we could wave to solve all the problems of fish abundance, has proved to be practically impotent. Although few marine fish hatcheries persist today, these, and many fresh water hatcheries too, exist because part of the public will not accept as proven one of the best documented cases in biology: that is, hatcheries often do not do the job expected of them (Foerster, 1931; Hammer, 1946; Rounsefell, 1947).

Early evaluations of results of stocking marine fish in Scotland by Fulton (1910) are still among the most convincing. Fulton claimed a great influence to have been exerted on the numbers of young plaice on the beaches of Lochfyne by the liberation of fry, and based this claim on a considerably higher catch per hour's pushnet fishing in years when fry were liberated compared to catches in years when natural reproduction alone was allowed to supply the stock. In the years 1896-1901, when 4, 21, 16, 19, 30 and 51 millions of fry respectively were liberated, pushnet fishing produced 88 young fish per hour. In the years 1903-1908, when no fry were liberated, pushnets produced only 40 fish per hour.

Yet, despite this difference, there was no consistent relationship from year to year between the total numbers of fry released and the density of young fish later found on the beaches and expressed as catch per hour. It is true that the density of young fish was highest in 1901 when the greatest numbers of fry were released, but there was no relationship in other years. The second highest density, for example, was in 1905, when *no* fry were released, the third highest in 1896, when the smallest number of fry (4 million) were set free; the fourth highest was in 1898, when 19 million fry were released, the fifth highest in 1900 when 30 million were released and the sixth highest in 1903, when no fry were released.

Furthermore, it is conceivable that the higher average catches in the first six years compared with the second six could have resulted from a cyclical variation in abundance, since the years of fry liberation were in an uninterrupted series and not alternated with years when no fry were set free. This possibility is strengthened by Fulton's statement that "there have been complaints of the diminution of plaice in recent years, [i.e. during the second period, when no fry were released, and density of plaice was low] and this was proved to have occurred in the Firth of Forth from trawling experiments. If the adult plaice are decreasing and have for some years been decreasing, it might account, in part at least, for the reduction in average catch of the young plaice in Lochfyne in the second years of the experiments."

Many factors, often little understood, apparently have a much greater effect on abundance than does artificial stocking. Hatcheries seem to offer little hope.

Hatching must be distinguished from fish cultivation (Coker, 1956). From results of cultivation of oysters, clams and mussels, it is clear that if it is economically attractive to do so, this approach can foster great increases in production. Galtsoff (1952) points out that the yield of shellfish beds (500 - 750 pounds of meat per acre) can exceed that of the best agricultural lands. But this can be brought about only with careful cultivation of the beds. Planting of culch and seed alone is not sufficient. This seems to indicate the value of private planting of oysters on managed leased grounds, as opposed to wider and more wasteful governmental planting and indiscriminate harvesting of public beds (Radcliffe, 1950).

Brackish water pond culture of fish is successful in some parts of the world, notably Asia. The Valli da Pesca, between Venice and Chioggia in Italy, is a European example of this technique (D'Ancona, 1954). Even here the method has been criticized as inefficient. High cost of production in relation to return may well also be a serious deterrent to brackish water pond culture in the United States.

Recently attempts have been made in marine waters to fertilize enclosed areas and thus raise the basic productivity by increasing nutrients available and hence the size of each production level in the food pyramid

(Gross *et al.,* 1946). Some of these trials have been successful, and as a result some rather incautious projections have been made of the future of artificial fertilization of the sea. Most authorities agree that this technique is of limited application, and at best can be used only in special favorable circumstances where suitable enclosed areas exist. In the open sea rapid dilution of added nutrients can hardly be avoided and amounts of fertilizer needed to raise the productivity of a sizable area is far beyond practicability.

Instead of adding still more fertility to the ocean to augment the vast quantities already being contributed by rivers, it would be better to devise some means of making available the nutrients trapped in the deeper waters below the euphotic zone. This "plowing of the sea" may not be a totally fantastic idea, and serious attention has been given to it by responsible scientists (Taylor, 1953; Graham and Kesteven, 1954). To create artificial upwellings from abyssal depths would take staggering amounts of energy. Taylor calculates that it would require 5.64 million tons of coal to raise the temperature of a cubic mile of water 10°C. — an obviously impractical quantity. But he suggests (as do Graham and Kesteven) that it might be feasible to use the "waste" heat from nuclear reactions. If artificial upwelling could be brought about where it would send water into an area "sufficiently seeded with the necessary biota" it might produce great quantities of marine life, including edible fish. Taylor is of the opinion that "If the rich deep abyssal waters could be transported upwards in really great quantity only two miles from the bottom to the surface of the sea, the world could cease worrying about the source of animal protein food."

The technique of transplanting fish from crowded, food-scarce areas to more favorable habitats, while successful, for example, with certain populations of plaice in the North Sea (Taning, 1952), can be applied only in limited favorable areas, such as the Danish Limfjord and Belt Sea, and only on a scale which is insignificant for increasing the total yield from the sea (Graham and Kesteven, 1954).

The Control or Encouragement of Fishing Effort

The most immediate practical help that fishery science can give to the fishing industry is the promotion of operational efficiency. To be really helpful now, scientific investigation should lead to modifications in fishing methods which allow the maximum catch. Frequently restrictive fishing regulations have been imposed because of the pressures of special interests, or erroneous ideas. Taylor (1952) forcefully, and quite properly, attacks the timidity and negative thinking which has imposed crippling restrictions on fisheries. Some unnecessary restrictions in force on publicly-owned fishing banks have put the fishing industry at a disadvantage when competing with industries whose operators own and efficiently manage their own sources of supply. According to Taylor (1951 and 1952), it is not shortages of fish in United States waters that prevent catches from being larger, but rather it is the lack of demand for fisheries products. There is much truth in this, but there are exceptions. It is well known that some populations of valuable fishes have been reduced to dangerously low levels by overfishing or otherwise. Examples are the California sardine *(Sardinops caerulea),* Pacific halibut *(Hippoglossus stenolepsis),* Alaska salmon *(Oncorhynchus* spp.) Atlantic shad *(Alosa sapidissima),* as well as several North Sea fishes. But if there are added to this list the other fish stocks of damaged species, there probably remains many marine fish stocks that could stand heavier fishing. Increased harvest of these can come only, as Taylor contends, with increased demand, and this, in turn, requires more efficient production on marketing of fish. Showing the fisherman how to put his catch on the market cheaply and in such condition that it will be in demand over competing products is an important responsibility of the fishery scientist.

Efficiency can be promoted by showing fishermen where and when to fish so that bigger catches can be made with less effort. Often, bigger catches can be made with a minimum of artificial restrictions on the catch. However, judicious regulation of the catch in a specific fishery may be necessary and the acceptance of the position that fishery regulations are often unnecessary should not imply that *no* regulation of marine fisheries is ever desirable. As Graham (1943) has shown, inefficiency follows overfishing, and where this condition exists, fish catches can be increased by reducing fishing effort.

Not long ago the main job of the fish conservationist was "saving" of fish by restricting fishing. The newer idea that an abundant fish population can be wasted or actually harmed by underfishing is still hard to sell to the public and many administrators. One of the important contributions which biology can make will be to explain clearly the case for exploitation of a fish population to the limit of its potential yield. The biologist should also determine whether reduced catches are due to the changes in abundance which always follows the start of exploitation and which cannot be avoided if the fish are to be used; whether they are due to changes in hydrographic or other conditions beyond man's control; or whether they are avoidable reductions in abundance caused by overfishing.

The concept of the optimum yield of fisheries holds that for every fish population there is a certain maximum harvest that can be taken from it perpetually, and that there is a corresponding optimum fishing effort. This concept has had wide acceptance in recent years, but has been declared by some to be unworkable in practice (Taylor, 1952). However, in many fish populations, either because of their biological characteristics, or because of the nature of the fishery, the size of the optimum catch cannot be determined, or the knowledge of it, if determined, cannot be applied usefully. It should be emphasized that there is no fixed optimum catch for any species and the optimum catch changes under influence of environmental conditions. Hence any forecast of the size of the permissible harvest which will not endanger the stock must be approximate and may change over the years. However, careful observations, given favorable conditions in the fishery, should allow prediction of changes in the optimum population size, and possible changes in the optimum catch. Flexible regulations based on such information are better than unrestricted fishing, which may lead to damaging over-exploitation, or enforced underfishing with many resulting losses through underharvest. This is true even though our information may not be precise because of lack of tools and techniques for measuring the complex factors on which decisions are based. It is likely that in the future the tools and techniques will improve.

A few examples of this approach may be cited. For the fisheries of the North Sea, Carruthers (1954) estimated that catches could be increased by 15 percent by relaxing fishing pressure. The British Ministry of Agriculture and Fisheries (1953) in retrospect suggests that for plaice, haddock and cod a 20 percent increase in catches in the 1930's could have been realized from the North Sea by halving the fishing effort. In such cases increased landings could have resulted from reduced fishing effort. Such a situation could result in increased efficiency and higher quality products at lower prices, which in turn could lead to increased demand for marine products and fuller exploitation of under-used resources. It is apparent that in commercial fisheries biology and economics are closely connected.

HYDROGRAPHIC CONDITIONS AND THEIR EFFECT ON FISH DISTRIBUTION AND ABUNDANCE

Sverdrup (1952) declares that the chief responsibility of the fishery scientist is to make predictions of two kinds; predictions of availability, and predictions of the size of the stock.

Predictions of availability involve correlations between hydrographic conditions (*e.g.* temperature, salinity, pH) and the occurrence of fish. Carruthers (1954, 1956) questions the real value of this approach because of the small area of ocean which can be examined and the statistical chance of non-conformance of fish behavior with the oceanographic pattern. However, Japanese fishermen have increased their catches of deep-swimming tuna by location of schools with the aid of a thermometer (Shapiro, 1950). British fisherman locate "cod water" around Bear Island in two locations at two different temperatures (Lee, 1952). "Whiting water" (Russell, 1935) and "herring water" in the English Channel (Jensen, 1952) and the occurrence of tuna off the coast of France (Danois and Belloc, 1921) are also located by temperature. North Sea herring fishermen (Hardy, 1926) and Barbados flying fishermen (Wiles, 1952) have successfully used plankton samplers to increase their catches.

The researches of Bull (1952), Hiatt *et al.* (1953), and others, pointed out that a fuller understanding of reactions of fish to environmental conditions together with simple methods of measuring hydrographic conditions applied to location of fish concentrations could easily lead to greater efficiency of fishing operations. Such an approach can show where and how the gear should be fished and can assist in the design of gear. A final step is the translation of such information into clear-cut instructions for fishermen, such as instructions for the use and interpretation of thermometers, bathythermographs and plankton indicators.

Development of this field is contingent upon greater cooperation between the oceanographer and the fishery biologist and the coordination of data gathered by both disciplines.

A future task of the fishery scientist and oceanographer is prediction of occurrence of oceanographic conditions and relationships. This is difficult work and little success has as yet been achieved. It awaits fuller description of the oceanic environment.

THE ELUCIDATION OF PATTERNS OF FISH BEHAVIOR

Fishing efficiency can be increased by a better understanding of fish behavior. A considerable portion of a fisherman's skill is based on his accumulated first-hand knowledge of fish movements, schooling behavior and feeding habits. Fishery science can do much to supplement, organize and disseminate this knowledge.

The echosounder and echoranger are of considerable help in this connection. Improved instruments and greatly increased skill in interpreting echo traces have made this technique of more and more value (Hodgson, 1950; Cushing, 1957). The Norwegian research vessel, *G. O. SARS,* has been so successful in guiding fishermen to schools of herring, whose position was formerly unknown, that the fleets can now work profitably for a much longer period of the year. The value of increased catches for a single season have exceeded the cost of the vessel. Fishermen have been so enthusiastic about the results that they have demanded a second vessel; but unfortunately, this cannot be adequately staffed because of the present lack of trained fishery scientists.

Kesteven (1953, 1955) points out that there is some information about reaction of fish to wind, tide, approach of storms (and even impending earthquakes), but that this knowledge is far from complete and is not available for practical use. Reactions of fish to light form the basis for a few kinds of fishing gear, particularly Japanese gear (Kask, 1947). Its successful use suggests the need for research in this direction. Reactions of fish to odors are likewise worthy of study. Surprisingly, little is known about the efficiency of different kinds of baits in such fisheries as the crustacean trap fisheries. It is likely that the messy, haphazard methods of using old fish and other discarded material for lobster and crab bait will eventually give way to use of long-lasting artificial baits of uniform and high efficiency.

The rapid appearance of sharks and other carnivorous fishes at an area where small fish have been caught or injured suggests that sound may be an attracting force. The fish often come too rapidly to have been stimulated by the odor of blood, and it seems possible that injured fish make a characeristic sound which suggests an easy meal to the predator. Recordings of these "hurt" sounds played back in a suitable area, might prove a potent attractant to fish which when concentrated might be surrounded by a net, or pumped aboard a waiting vessel. Also, more attention deserves to be given to behavior of fish in an electrical field, and the reports that the menhaden fishery is actively engaged in such work is encouraging.

An interesting paper by the staff of the Fisheries Division of the Food and Agriculture Organization in Rome (1953) concludes the section on fish catching with this paragraph. "To summarize in respect of the fish catching techniques, we may say that these also are developing towards a substantial reduction of uncertainty of fishing operations, and that, coupled with the advances in fish finding, the conclusion is that fishing operations are becoming steadily more certain and, therefore, that they should be more susceptible to national planning in relation to the potential of the stock."

Prediction of the Abundance of Fish

Forecasts of future abundance by the study of the strength of year classes and of the abundance of eggs and larvae, although not noticeably successful as yet, are gradually improving in accuracy and can be expected to continue to do so. Such predictions can be of great help to the fishing industry by increasing operational efficiency.

Study of the oceanographic factors determining strength of year classes is a highly complex and separate field. Tait (1952) mentions a number of hydrographic factors which affect the success of spawning and the survival to maturity of marine animals. Among the most important of these are temperature, depth, pressure, salinity, oxygen content, light, food and currents. He regards temperature as having a very important effect, and suggests that currents are of "supreme (and) fundamental importance . . . Currents control the distribution of temperature and other physical and chemical properties of the sea. They control the distribution of the ultimate food organisms on which all marine life depends. They control, further, the dispersal of fish eggs and of the youngest fishes until they acquire motive power of their own and in the reproductive stage of a fish's life . . . they govern, very largely, the movement of fishes towards the places where these physical conditions exist in which alone reproduction will take place."

Tait discusses the interesting connection which seems to exist between the simultaneous successful survival of certain year classes of several populations of fish (e.g. Norwegian cod, Norwegian herring, Newfoundland herring) and the peculiarities of the oceanic currents in these years.

The opinion that ocean currents have a great effect on fish survival is shared by Carruthers (1954) whose researches (as well as those of Veley and others) have shown good correlations between currents as expressed by wind data, (for lack of accurate and extensive current information) during and after the spawning of haddock in the North Sea and the abundance of adult fish resulting from that brood.

The great complexity of the relationships between hydrographic phenomena and fish abundance has prevented any great advance in this aspect of fisheries science, but new methods and new insight promise progress in the future.

In the long run, biology and oceanography can make their most important contributions to increased fish catches only by unravelling the immense complex of ocean ecology. We are certainly not getting the maximum benefit from our sea resources, and we will not do so until we have an understanding of the size of fish stocks, the behavior of the fish and the effect on them of hydrographic conditions and changes. Earnest, concentrated, and intelligently planned research is called for and to a degree not achieved so far. As Smith and Chapin (1954) point out, expenditures for research on sea problems are but a fraction of one percent of those spent on agricultural research. And increases in funds for marine research come painfully slowly.

Approaches such as the production of artificial upwellings, although appealing in their novelty and dazzling possibilities are as yet far removed from practicability, and should not divert attention from the main task, which is increased effort (both in quantity and quality) on basic biological and physical studies of the fish and their environment. With such increased effort it is certain that greater yield of food from the ocean can be obtained and this can do much to ameliorate any future crisis in fish production.

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INFLUENCE OF TECHNOLOGICAL ADVANCEMENTS ON UTILIZATION OF FISHERIES IN THE FUTURE[1]

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ABSTRACT

A summary of recent technological advances in commercial fisheries is presented. Application of these can eliminate waste and loss, extend storage life of fresh and frozen fish, reduce production costs by design of production lines, develop new fisheries products, increase quality of present products, and develop new uses for processing wastes. The fishing industry must adopt new technological advances if it is to compete with other food-producing industries.

INTRODUCTION

During the next twenty years, the world will be faced with a major problem of providing an adequate supply of animal protein for a continually increasing population. It has been estimated that by 1975, there will be a shortage of approximately 1.5 billion pounds a year of edible fish in the United States alone. This estimate is made using two assumptions, which may or may not be true: (1) that per capita consumption of fish will not increase; and (2) that it would be better to meet this deficiency by the expansion of native fisheries than by increasing imports. Prediction of the influence of technological advancements on the utilization of fisheries in the future can best be approached by consideration of the past.

In some fields of endeavor, such as that of electronics, nucleonics, and missiles, imaginative thinking and long-range planning have been encouraged and have been extremely remunerative. In such areas, the future is restricted only by imagination. On the other hand, the short-term, day-to-day approach of the fishing industry to its problems, its ultra-conservativeness and even its regressive approach in most matters, force the conclusion that the future of the fishing industry is apt to be but a short extension of its past.

Per capita consumption of fish in the United States has only maintained its position at 10 to 11 pounds per year while, according to the 1957 World Almanac, per capita consumption of other protein foods has increased: cheese from 5.5 to 7.8 pounds; meat from 125.3 to 161.2 pounds; chicken from 13.2 to 22.5 pounds; and eggs from 296 in number to 418.

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This failure of fish to meet the competition of other protein foods indicates either a lack of acumen or vision, or both, by persons in research and management in the fishing industry.

APPLICATION OF TECHNOLOGICAL ADVANCEMENTS

In the past, the application of technological advancements and know-how have often been ignored in the fishing industry. This has been the result of business and economic policies which have for the most part been backward or regressive. The general attitude has been that expressed by such statements as: "I can sell every pound of fish I can get my hands on, so why bother?" or, "What good is research going to do me when I'm chasing a quarter of a cent on the market?" Such negative attitudes have for the most part stifled application of technology to the problems inherent in the fishing industry.

To some extent, these attitudes have been encouraged by the lack of education of the industry to the need for basic research. Sometimes research organizations themselves have contributed by adopting a policy of "greasing the squeaky wheel" and giving attention to applied research where industrial pressure has been greatest.

Assuming that present thinking persists, the possibilities for the future consumption of fisheries products by humans are not bright. This has been very well put by Dr. C. L. Cutting (1955) of the Food Investigation Organization, Department of Scientific and Industrial Research, United Kingdom, in his recently published book entitled *Fish Saving*. Dr. Cutting says:

> "Another possibility that arises is that most of our fish, particularly cod with their relative tastelessness, and herring, etc., with their bones and indigestibility, may be unable ultimately to compete with unlimited supplies of fresh meat in perfect condition. In that event, fish meal may indeed be the only outlet for fish other than a limited few with a particularly delectable flavor, such as halibut and salmon."

Perhaps in the static statistics of per capita consumption, we see the beginnings of such a decline.

To survive growing competition and meet demands of an increasing population, the fishing industry must develop enlightened managerial policies and long-term research programs. And such policies must develop and take full advantage of technological knowledge of the meat, dairy, and cereal industries. The use of technological personnel and knowledge by and in the industry — not only in product development and quality control but in cost accounting and production — can lead to elimination of wasteful practices, increased efficiency, and financial gain for the industry

Even if we only exploited our present technological knowledge, it is conservatively estimated that elimination of wasteful practices now prevalent in the industry could add a quarter billion pounds to fisheries products available for human consumption. Such a saving could do a great deal to ease today's tight margins of profit, or could alleviate a significant portion of the predicted shortage of edible fish in 1975.

Without application of present knowledge and without policies and programs for obtaining additional information, decline in human consumption of fish is imminent. Granted, information costs dollars, but with it, the chances of successful enterprise are great, and ultimately, the costs of obtaining information are returned manifold.

To illustrate these points, there is the lesson of fish stick production which has been learned at great expense by many in the fishing industry. Fish sticks are a product developed by technologists in 1953. Successful production of fish sticks requires strict technological control.

Yet, when the market began to mushroom, many concerns began production without any idea of the difficulties which would be encountered. Production lines frequently were makeshift conglomerations of machinery sold to the producers by the different equipment houses and purchased with the idea that the only matter of importance was quantity production. In the mad scramble to get into production, only a few concerns considered the idea that a production line, like a high fidelity system, yields most for the money when it consists of properly constructed and integrated components. When the market began to stabilize, many of the companies were forced out of the field. Those companies which applied and used technological knowledge still are profitably manufacturing large quantities of fish sticks.

In the past, there have been technological advancements, but there also have been long delays between development and application. To mention but one example, the use of refrigerated brine for the storage of fresh fish was proposed to the industry as early as 1931 by Huntsman. The method with its attendant advantages of circumferential cooling, lowered temperatures, and lack of pressure results in an extended keeping time for fresh fish. Yet there was more than a twenty year lag between proposal and commercial acceptance.

There are many other examples to choose from: not only in the field of production and product development, but in gear development, ship design, transportation, and the like. Consequently, one must predict that most future developments will result from the extension of practices just beginning to be applied and the application of present knowledge which, because of economic barriers, has not as yet been used.

Of course, possibility always exists for development of new processes which will make older methods of preservation and handling of fish obsolete. However, throughout the history of mankind, the development of new methods of food preservation has supplemented rather than supplanted older methods. It is extremely unlikely, therefore, that present fish processing and handling methods will be replaced during the next fifteen to twenty years.

However, with a favorable attitude toward the application of technological information, one can foresee changes in practically all aspects of handling of fish.

Aboard ship, there will be increasing use of refrigeration in combination with ice as well as the use of refrigerated brines for the storage of fresh fish. This will permit longer trips to more distant grounds, without comparable loss of quality, or increased quality, with less loss, on trips to present fishing areas.

The use of antibiotics and other chemical agents in conjunction with refrigerated brines and ices will further extend the storage life of fresh fish. Under such circumstances, one can well imagine the elimination of extra labor costs necessitated by canning salmon in Alaska. Refrigerated vessels could bring the catch to Washington and Oregon, where the labor costs are lower.

In like manner, species will be utilized which are not landed at present because of rapid deterioration of quality under today's handling conditions or because of the remoteness of the fishing grounds.

The freezing of fish at sea will, at least, be further investigated. Depending upon the economic pressures, it may at last become a widespread method of handling fish. The techniques for freezing fish at sea have been developed in studies which began prior to the turn of the century. Failures of this system have occurred because of socio-economic rather than for technical reasons. This system, perhaps, offers most hope for the successful solution of the future crisis in fish production. As the White Fish Authority of the United Kingdom (1952) has stated: "The development of a method of freezing at sea is essential if the most is to be made of the distant-water fisheries." However, its successful application depends upon the severity of the crisis. Harden F. Taylor (1951), in discussing freezing at sea, has said that although:

> "Most of the experience . . . (of these attempts) to ameliorate the difficulties deriving from remoteness and perishability . . . has turned out to be disappointing . . . yet herein lie the problems that must be solved if the resources of the sea as a whole are to be fully put to use. The reason why the remote fisheries of the world are not exploited is . . . that it does not pay to exploit them."

If the world crisis in fisheries production is severe enough, such fisheries will be able to compete financially.

Commercial freezing of fish at sea can have far reaching consequences. For one thing, it may revolutionize the distribution of fish, resulting in the demise of fishing ports located away from population centers. Inland deep water ports such as Chicago, Cleveland, and Milwaukee will become major primary distribution centers.

On shore, other changes will become evident. Quality control will become more and more important in the industry. It is likely that its implementation will in some cases be voluntary, as it is today under the Fish Stick Standards program. In other cases, it may well be forced either by the federal government, as in the Tuna Standards Program, or by the mass buying power of the consumer as evidenced by the pressure brought to bear upon the industry by chain-stores and buying co-operatives.

At the same time, several of the present market forms of fresh fish — whole, eviscerated and pan-ready — may disappear from the shelves of the retailer, giving way to portion control and its attendant package.

The package in itself can be expected to change from a simple overwrap to a flexible, impermeable film upon which a high vacuum can be drawn and in which fish portions can be packaged with the rapidity of a high speed cannery line. Such a package will, in turn, extend the shelf life of the fish. It is entirely possible that true fresh fish, as we know it today will disappear from the markets. There is evidence that when fish are properly handled, packaged, and frozen, they can be stored for considerable periods of time and shipped long distances, then thawed and sold as fresh fish and still be of better quality than "fresh fish" handled and shipped by present methods (Hartshorne *et al.,* 1952).

Such a process involves the use of lower frozen temperatures (–25° to –40°F.) than in common use today (O° to –10°F.). The use of the lower temperatures which retard deteriorative changes has been recommended for many years (Tressler, 1950), but the economics of the industry have not as yet warranted the conversion of present facilities.

Other than the use of lower temperatures, there appears to be little room for improvement in freezing of fish beyond that already obtainable by the proper application of present and widespread — but not widely applied — knowledge. However, the proper application of our present knowledge can lead to the use of species which now are thought to be unsuitable for marketing in the frozen form.

One can foresee the application of high-temperature-short-time canning processes to particulate products such as canned fish, enabling a cannery line to double, if not triple, its daily production.

Radiation sterilization and pasteurization also will be an available process in the future. Perhaps this process will not be commercially feasible by 1975 but certainly sometime shortly thereafter. Improved processing and distribution methods will tend to alleviate the predicted shortage by acting to smooth out peaks and valleys of production and catch. The two primary problems remaining to be solved are off-flavor development and cost of processing.

There will be new products for consumer convenience of the heat-and-eat type and perhaps the utilization of by-products as more expensive pharmaceutical products rather than as fertilizer or fish meal. This latter development will be a necessity if the industry is to have its products compete for the consumer dollar with meat, where a great deal of the cost of production is already amortized by the results of extensive research on by-products use.

In summary, technological advancements, given a favorable climate for development and application, can aid in the alleviation of the predicted crisis in production. Influence of these advances will be felt in several ways including elimination of waste and loss, extension of the storage life of fresh and frozen fish, reduction of production costs by the design of production lines and resulting increase in production rates, utilization of new processes and development of new products, improvement and standardization of quality, and the development of new uses for the waste materials from edible fish processing.

Such developments need not wait for the future. They are obtainable today, but their application is limited and restricted by pressures and economies. Meeting the predicted production shortage is in the hands of the fishing industry. Professional fisheries workers can only guide, suggest, and recommend. But it would be well for both us and the industry to remember that "The future is a world limited by ourselves . . ."

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UNEXPLOITED POTENTIALS OF OUR FRESH-WATER COMMERCIAL FISHERIES

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Abstract

As need for greater food production increases during the next 30 years, the yield of fishery products must be increased. One source of this increase can be our relatively unexploited fresh-water commercial fisheries, particularly those of reservoirs, rice fields, farm ponds, and fish farms. Much additional research must be conducted on utilization and marketing of the products of these fisheries, as well as on improved harvesting methods, and legislation and public relations. A comprehensive program of public education on the general dynamics of fresh-water fish populations is vital, in order to alleviate the unnecessary conflict that exists between sport fishermen and commercial fishing.

Introduction

The fresh-water commercial fisheries of the United States have, up to the present time, contributed only a very small percentage (less than 0.2 percent) of the basic protein food (meat, poultry and eggs, fish, shellfish) consumed annually in this country. In 1954, the latest year on which separate and complete data are available (Anderson and Power, 1956), the total catch of the fresh-water fishery was 141,254,000 pounds (excluding shellfish); 3.4 percent of the total fish catch of the commercial fishery of the United States and Alaska. The value of the fresh-water catch was $17,182,000; 7.8 percent of the value of the total commercial catch. These data are for the lake fisheries (Great Lakes, Lake of the Woods, Rainy Lake and Lake Namakan) and the Mississippi River fisheries; the only two fresh-water fisheries of any consequence at the present time.

It is not the purpose of this paper to present data supporting or refuting the idea of a crisis in fishery production during the next two or three decades, but rather to point out how the proportion of the total fishery production which the commercial fisheries of our fresh waters provide can be increased. Whether such an increase would help to alleviate the predicted production crisis, or simply contribute to the expansion of an old but still expanding industry, is immaterial. The potential of our fresh waters for producing large quantities of fish for food and other purposes is great and it is largely unexploited. Judicious exploitation could be an asset to the economy of many areas of this country.

Shortly after the beginning of World War II, many papers were published on the subject of increasing fishery production to alleviate the possible food shortage which the war might produce (papers such; Green, 1942; Higgins, 1942; Jackson, 1942; Viosca, 1942, 1945; Wiebe, 1942; Gray, 1943; Skiff, 1943; Van Cleve, 1943). Most of these papers dealt with the fresh-water fishery. Most of what was said then can still be said today, and there is very little to be said today that is new and different from what was said then. Fish consumption, as well as the methods of fishing, are essentially the same; and we still hear the same arguments against extensive commercial fishing in inland waters. About the only thing that is significantly different now is the increased number and acreage of reservoirs and farm ponds, and the recent acceleration of the development of fish farming, especially for trout, in this country.

It would be presumptuous to suggest an expansion of commercial fishing in fresh waters as a partial solution for a production shortage or a method of expanding the commercial fishing industry without at least summarizing some of the reasons why such an expansion has not already occurred. A basic reason seems to stem from the fact that by preference ours is essentially a meat-eating nation with fish well down the line of basic protein foods as far as per capita annual consumption is concerned. Estimates of per capita consumption for 1957, published by the U. S. Fish and Wildlife Service (1957), and based on data of the previous two years are as follows: total meat—159 pounds (beef—81 pounds, pork—64 pounds, veal—9.4 pounds, other—4.6 pounds); poultry and eggs—25 pounds; fishery products—10.1 pounds. The latter includes shellfish and canned products to which the fresh-water fishery makes no appreciable contribution. Annual per capita consumption of meat, poultry, and fish has varied only slightly since 1940. Fish has remained the most constant; the others have slowly increased.

Other important reasons for the low exploitation of our fresh-water commercial fishery are the ever-present conflict with sport fishing interests, the limited market for the catch, and the greater effort involved in producing a sustained yield large enough to be profitable. The laws pertaining to the inland waters of most states are designed to protect the sport fishery; thus they often either prohibit commercial fishing or so thoroughly hamstring it that its practice is not feasible. In most areas such laws are gradually being liberalized, and as public education regarding sport fishery management improves, the prejudice against commercial fishing should diminish.

An increase in the production of our fresh-water commercial fishery depends primarily upon need and research. The need will almost inevitably produce the research, but it would be better if the research could produce the knowledge to alleviate the need before a production crisis actually occurred.

It seems evident that the increase in the commercial fishery production of fresh waters will be derived chiefly from the establishment or expansion of four general fisheries: reservoirs, rice fields, farm ponds, and fish farms

Certainly the production of the Great Lakes and other natural lakes, and the Mississippi River and other streams can be increased, but the increase is limited primarily to the exploitation of species of little value at the present time.

THE RESERVOIR FISHERY

The fresh-water commercial fishery perhaps in greatest need of exploitation is that which could be provided by the many reservoirs now in existence. The total area of these reservoirs (federal, municipal, private enterprise) exceeded 11,046,300 surface acres in 1954 (Thomas and Harbeck, 1956). The combined storage capacity was 278,121,200 acre-feet. Additional reservoirs have been built since 1954, or are now under construction, and many others are proposed. From studies of the fish populations or of yields of commercial fishing in some of these reservoirs (e.g., Bryan and Tarzwell, 1941; Bennett, 1943; Rounsefell, 1946; Patriarche, 1953; Schoonover and Thompson, 1954; Houser, 1957) it is evident that most are quite productive with large annual crops of fishes of actual and possible commercial value. It is common knowledge among biologists and fishermen that after an initial period of abnormally high game fish production, fish population structure in these reservoirs changes and the larger percentage of the fish population is then composed of rough fishes, ie., gar, gizzard shad, buffalo, carpsucker, carp, etc. Although few thorough studies have been published on yield and standing crops of reservoir fishes, those of Thompson (1941), Tarzwell (1942), Wiebe (1942), Jenkins (1951), and Thompkins, Barber, and Gerow (1951) give data which show the predominance of rough fishes.

To arrive at an accurate average figure for the standing crops per acre of fishes of commercial value for all of the reservoirs in the United States would take far more data than is now available. Since a large percentage of the total reservoir acreage occurs in the southern half of the United States (Thomas and Harbeck, 1956) where production is higher than in the colder more northern waters (Thompson, 1941) an estimate of the standing crop of 100 pounds per acre is probably conservative. Wiebe (1942) gave 100 pounds per acre as the standing crop of TVA reservoirs. An active, properly regulated commercial fishery should be able to harvest a sustained yield of 30 percent of the standing crop, or 30 pounds per acre (this too is certainly conservative). If this yield could be taken annually from the total of all of the acres of reservoirs (11,046,376), the total production would be 331,391,280 pounds, almost two and one half times the present annual harvest. Since this yield would come from waters only lightly fished at the present, most of it would be in addition to the present fresh-water catch.

THE RICE FIELD FISHERY

The rice fields of Arkansas, Texas, and other rice producing areas of the United States have a great potential for fish production. Senator Fulbright of Arkansas, in a hearing on Senate Bill 1552 before a subcommittee of the U. S. Senate Committee on Interstate and Foreign Commerce, 1957, reported that about 300 rice-fish farmers farm about 60,000 acres in Arkansas, and harvest an average of 500 pounds of fish per acre — a total of 30,000,000 pounds per year! Add to this the acreage of rice fields in other states plus the ever greater pond-per-acre production that scientific research would produce, and the total annual fish production from rice fields would be tremendous. In order to get such large yields the fishes used would have to be those with a short food chain such as carp, carpsucker, and buffalo. A more profitable venture, although one that produces a smaller annual yield, is the raising of channel catfish in the rice fields. I know of no reliable figure on channel catfish production at the present time, but considerable data should be available in the near future. As a part of the study of the propagation requirements of this species, which we are conducting at the University of Oklahoma as a Saltonstall-Kennedy project, we have stocked channel catfish in a 100-acre rice field in Texas. Growth rates and production are to be determined this fall.

If a serious fishery production shortage should occur it might become desirable or even necessary to introduce species that produce extremely large yields in certain parts of the orient. Dr. Swingle has already worked with *Tilapia mosambica* in Alabama, and has learned that yields as large as 3224 pounds per acre can be produced in ponds. Equal or greater yields could probably be raised in rice fields.

THE FARM POND FISHERY

A sizeable and productive fishery could be provided if farm ponds were used for production of fishes of commercial value. There are about 1,250,000 farm ponds in the U.S. at the present time and the number is increasing steadily. The combined area is about 500,000 acres. The yield of the average farm pond in the United States is not comparable to that of ponds in Israel (Jones, 1956), Japan (Kawamoto, 1957), and other oriental countries; however, yields of 100 to 300 pounds per acre should be fairly consistent (Dugan, 1951; Carlander and Moorman, 1956) without intense effort on the part of the pond owners. The application of the best-known methods of fish production in farm ponds would increase the production considerably, and basic research on the use of native species (e.g., buffalo, carpsucker, bullheads, channel catfish) may make possible even greater yields. Based on an estimated standing crop of 150 pounds per acre, a harvest of 50 percent of this standing crop, and an additional estimate that one third of these ponds could be utilized for fish production, a total of 12,500,000 pounds of fishes could be produced.

FISH FARMING

Possibly the greatest source of increased fishery production from fresh waters could come from intensive fish farming. At the present time only a very small amount of fish farming is carried on in this country, unless the activities of state and federal fish hatcheries and commercial minnow hatcheries is included. Lucas (1931) reviewed fish farming in the United States up to 1931. Since that time there has been an expansion of trout farming and the addition of channel catfish farming. The latter should expand considerably during the next few years. Our first two years of work at the U. S. Fish Cultural Station at Tishomingo, Oklahoma, and at the University of Oklahoma at Norman, on the propagation requirements of this species indicate that channel catfish farming can be a sound, profitable business. By inducing pairs to spawn in aquaria with injections of pituitary hormones we produced approximately 500,000 fry in the hatchery holding house during the 1957 spawning season. This basically simple technique applied on a commercial basis, by anyone with an average amount of basic biological training, will remove most of the uncertainty from the propagation of this species.

The greatest production of fresh-water fishes by fish farming will not come from raising such species as trout or channel catfish, but more prolific species with short food chains such as buffalo, carp, and bullheads. Hendricks (1956), stated that the smallmouth buffalo does well in ponds; data of Carlander and Moorman (1956) indicated the same for the bigmouth buffalo and the bullhead. Other species (e.g., carpsucker, gizzard shad, thread-fin shad) also have great possibilities and additional research must be done on pond culture of these and other species.

The question of how much fish farming can add to the annual fishery production will surely depend on need and utilization of the available species. Based on production in other countries, the addition can be tremendous.

UTILIZATION AND MARKETING

Before the suggested increase in fresh-water fishery production can ever become an actuality, the present methods of utilization and marketing must be vastly improved. Research has produced new methods of processing and packaging (e.g., fish sticks, fillets, steaks, and other frozen products) that have increased sales of marine products. Similar research must be done on fresh-water fishes and equally appealing methods developed before there can be the needed expansion in the market for many fresh-water species (e.g., carp, buffalo, bullheads). Canning, smoking, drying, quick-freezing, etc., now used only slightly or not at all for many species, all have excellent possibilities as methods of utilization. Research on processing is of vital importance to the expansion of the fresh-water fishery, and it will probably be up to the government agencies to conduct this research.

Those species that probably will never be popular as food fishes because they are too small, too bony, too oily, or distasteful (e.g., bloaters, gizzard shad, thread-fin shad, certain suckers), might be used for the production of other protein foods and supplements. Premetz (1956) discussed such uses as fish meal, fish oils, and fish food to be used at fish hatcheries and on fish farms. Certainly rough fishes could be used in the production of fertilizers. All of these products could aid in the production of other more popular and more palatable protein foods.

The development of portable freezing and processing plants would accelerate the expansion of our fresh-water fisheries. Getting the catch to the place of utilization while it is still fresh is a serious problem. Rarely is there an adequate market in the immediate vicinity of the fishery, and although the total production of a region may be sufficiently large to supply a freezing or processing plant on a year-around basis, the yield of one fishery in the region, e.g., a lake, a reservoir, a series of farm ponds, a fish farm, would often not be large enough. Distances involved often make the cost of transportation of the fish to a stationary plant prohibitive. A portable plant operating on a well-organized schedule, similar to portable fruit and vegetable canning factories, could solve the problem. Research on the development of such a plant has been reported by Premetz (1956).

The marketing problem cannot be solved only by the development of new methods of processing. The American public must be made more "fish conscious" as far as diet is concerned. This is, to a great extent, a matter of changing habits. In case of a severe food shortage hunger or need quickly changes habits, but since this should never be the case in the United States we must depend essentially on public education and advertising. The knowledge of what fishery products are available, tasty, and nutritious must be constantly presented to the people in the most effective way.

IMPROVED HARVESTING METHODS

Commercial fishery production in fresh waters is definitely hampered by the harvesting methods that are commonly used. Gear such as haul seines, trap nets, pound nets, etc., used commonly in the Great Lakes and to some extent in the Mississippi River, are rarely used in reservoirs. Use of such gear would not only increase the harvest, but would do little or no damage to the game fishes that would also be caught. The principle methods now used in the reservoir and river fisheries are gill nets, hoop nets, fyke nets, and trot lines. Gill nets, trammel nets, and trot lines often injure the game fishes that are caught along with commercial species so that they die when they are released. Mr. Alfred Houser, of the Oklahoma Department of Wildlife Conservation, has been experimenting with various types of commercial gear in Fort Gibson Reservoir, a 51,000-acre impoundment of the Neosho (Grand) River. A preliminary report on his fishing with a 1,450-foot haul seine indicates that about 1,100 fish per haul weighing about 600 pounds can be taken. The catch consisted of 80 percent non-game fish. He also built a small experimental trap net 50 inches deep; the pot was 7 feet long and of 3/4-inch mesh, the heart was of 1-inch mesh, and the lead was 200 feet long and of 1½-inch mesh. The catch of this net so far has averaged 160 fish per lift, weighing 70 pounds (59 percent of the catch was game fish). Houser feels that with more experience, and using a much larger trap net, the yield can be increased considerably.

The use of electrical fishing devices in fresh waters as a means of harvesting fish commercially should be investigated. Certain illegal methods used occasionally in Oklahoma are quite effective for taking large catfishes such as the flathead catfish and the blue catfish. Large electric seines should by very effective in reservoirs in taking large numbers of rough fish that tend to congregate in shallow water near the shore. The electric seine might also become quite useful in harvesting the crop on fish farms and from farm ponds.

LEGISLATION AND PUBLIC RELATIONS

Proper and adequate legislation, and a well-planned, well-executed program of public education on the benefits to be derived from fresh-water commercial fishing is absolutely essential to the success of an expanded program. The only valid basis for such legislation are the data divulged by scientific research. Experimental fisheries should be established in order to provide the data necessary for determining the feasibility of commercial fisheries in various waters. Such data should include: (1) The species available and the species composition of the harvest, as well as the expected yield and its value. (2) The effectiveness of the various types of gear for harvesting both sport and commercial species. (3) The amount of effort necesary to produce a profitable catch. (4) The optimum expoitation rate to assure a maximum sustained yield. (5) The effect of the commercial fishery on the sport fishery. With this information available overproduction and depletion could be prevented and the sport fishery could be protected. Also, production possibly might be increased further if the research showed that certain species frequently classified as game fishes (e.g., channel catfish, blue catfish, white bass, crappie) are sufficiently abundant and productive to be also classified as commercial species.

These data should also be used for public education. The fact that the expansion of the fresh-water fisheries is virtually impossible without public support cannot be overemphasized. If the sport fishermen of the region involved believe that their fishing is threatened by the establishment of a commercial fishery, the fishery is doomed to failure because it will not be maintained. Recent developments in Florida substantiate this. A commercial fishery was established and its value was proved by research (Dequine, 1950, 1952a). However, the public relations program did not convince the public of this value, and, in spite of the awareness of state officials of its importance (Dequine, 1952b), legislation was passed which abolished the fishery. Similar action has recently occurred at Reelfoot Lake, Tennessee.

Publications in state fish and game magazines such as those by Barber (1951), Riggs and Sneed (1951), May (1957), etc., are valuable in educating the public, but much more is needed. An extensive, informative, forceful program must be developed at both the federal and state level. Newspapers, magazines, radio, and television must be used to gain the public support necessary for the expansion of our fresh-water commercial fisheries.

Population growth will produce a need for an increase of 500 million pounds in the annual fishery production of the United States by 1965 (Whiteleather, 1957). If production must be increased by this amount, exploiting the potentials of our fresh-water commercial fisheries can contribute a large percentage of the increase.

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THE ROLE OF EXPLORATION AND GEAR RESEARCH IN THE FUTURE EXPANSION OF OUR COMMERCIAL FISHERIES

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Abstract

Exploratory fishing can aid the growth of our commercial fisheries by expanding present fishing grounds, diversifying effort on present grounds and discovering new fisheries. Development of better gear and catching methods through increasing gear research can help the domestic industry compete with foreign imports. Better fish-finding equipment is needed for more efficient operations. Midwater trawling and development of electrical fishing offer opportunities for additional fisheries of the open ocean. In the future, more emphasis should be placed on basic gear research by technicians who are especially qualified for this type of work.

Introduction

Exploratory fishing and gear research has played an important role in expansion of the domestic fisheries (Whiteleather, 1957), and even greater promise is indicated for the future. There is good reason to believe that methods and equipment eventually can be developed which will permit a commercial fishing harvest of all useful species on an optimum-catch sustained-yield basis, as determined by biological studies.

Some of our older fisheries are being exploited to their present maximum capacity. But many known species, such as Atlantic tunas, are underutilized. For full utilization of known fishery resources and discovery of new fisheries, we need better exploratory methods, more effective fish-finding instruments and techniques, and more efficient vessels, catching methods and gear.

Fish must be caught at a profit to the fishermen. Marginal and subsidized operations are not desirable even if they could fulfill production requirements. Unless world conditions change appreciably, the American fishing industry will continue to be faced with outside competition for domestic markets. Our fishermen must keep far enough ahead in mechanization and efficiency of operation so that they can compete with foreign fisheries having the advantage of lower labor costs. Any new item of gear or equipment must be practical and profitable to operate, and must meet established conservation requirements.

Exploratory Fishing Possibilities

Three principal ways by which exploratory fishing, with research vessels or commercial fishing craft, can aid in fisheries growth are: (1) expansion of present fishing grounds, (2) increased diversification of effort on the present grounds, and (3) discovery of new grounds and new fisheries.

EXPANSION OF PRESENT FISHING GROUNDS

The Pacific Coast tuna fishery, which has expanded from southern California to Peru in the last few decades, is probably the best example of expansion of a surface fishery.

Deep-water trawl prospecting by commercial fishermen has been productive off northern California, Oregon, and Washington. In 1950, practically all trawl fish landed in State of Washington ports came from depths between 10 and 100 fathoms. By 1954, only 4 years later, nearly 30 percent of the catch was made between 100 and 200 fathoms (Alverson and Powell, 1955). In the Gulf of Mexico shrimp fishery and the New England trawl fishery there also has been a recent trend toward deeper water exploration and production.

Traditionally, expansion of fishing grounds has resulted from occasional prospecting trips by commercial vessels, gradually going farther and farther from port. Increased operating costs, coupled with the inability of the exploring fisherman to place any legal claim on his discoveries, has made it progressively more difficult for industry to continue such activities. Consequently, more and more exploratory work has been done by State and Federal agencies.

There are undoubtedly opportunities for expansion of present fishing grounds for bottom fish and shellfish, as well as for some pelagic species. Researchers in this field must cooperate closely with the commercial fishermen, utilizing to the fullest extent the fishermen's experience and knowledge in planning and carrying out the projects, and in turn making results quickly and understandably available to the fishermen for their use.

DIVERSIFICATION OF FISHING ON PRESENT GROUNDS

Off Grays Harbor, Washington, the continental shelf for years has supported a trawl fishery for bottom fish, while a small fishery for shrimp existed in Puget Sound. It was known that shrimp were present on the offshore grounds, for the trawlers caught a few occasionally.

Last year, upon request of several industry members, the Fish and Wildlife Service's exploratory fishing vessel *John N. Cobb* surveyed the offshore grounds to determine their commercial shrimp potential. The project, carried out in cooperation with the Washington State Department of Fisheries, was succesful in demonstrating that pink shrimp *(Pandalus jordani)* were abundant over a large area off the Washington coast. It was found that they could be taken consistently in commercial quantities with a Gulf of Mexico shrimp trawl (Schaefers and Johnson, 1957). As a result, within one year after the explorations were completed a thriving shrimp fishery was under way out of Grays Harbor. Over a million pounds of shrimp were landed during the first half of 1957, and it appears that Washington will pass California as the leading shrimp-producing state on the Pacific Coast.

The foregoing example illustrates the possibilities for increasing production on known fishing grounds by harvesting different species than have been traditionally caught there. An area may be yielding its maximum production of one or more fish while others may be going to waste on the same grounds.

Utilization of trash fish from Gulf of Mexico shrimp grounds by animal food processors is another example of how diversified fishing can increase production from an area. In looking for new sources of fishery products we must be careful not to pay so much attention to distant waters that we pass up the unutilized species in our own front yards.

DISCOVERY OF NEW FISHING GROUNDS

Of all fishery research projects, there are few more expensive to operate than those which have as their objective the exploration of new fishing grounds. Often the waters under investigation are distant from home port. Large vessels, experienced crews, costly gear, and highly-trained personnel are required. Consequently, this type of undertaking has become more and more the responsibility of research agencies backed by government financing.

Working out of Hawaii, the Pacific Oceanic Fisheries Investigations has discovered extensive populations of mid-Pacific tunas (Shomura and Murphy, 1955). California's ocean shrimp fishery is a direct result of exploratory fishing by that State's research agency (Squire, 1956). Systematic exploratory fishing is also responsible for the Alaska king crab fishery and the discovery of Gulf of Mexico tuna, the fishery for which is just beginning.

For future oceanic exploration there are numerous possibilities. Research vessels operating off the Pacific Coast have found saury *(Cololabis saira)*, pomfret *(Brama raii)*, jack mackerel *(Trachurus symmetricus)*, hake *(Merluccius productus)*, and squids abundant in the offshore waters several hundred miles from shore. The *M. V. Oregon* has discovered anchovies and sardine-like fishes in the Gulf of Mexico. All these unutilized offshore species are resources of potential value to the American fishing industry—when they are needed, and when methods for their economic exploitation can be worked out.

GEAR RESEARCH AND DEVELOPMENT

Fishing vessels properly cannot be classified as gear, but since they are essential to the catching of fish we cannot overlook the importance of vessel efficiency. England, Germany and Russia have recently put into operation radically designed trawlers. These are big vessels, with whaler-type sterns for hauling the trawls and carrying new equipment for processing the catch on board (Anonymous, 1955a). With the exception of the California tuna clipper, there has been little progress in fishing vessel design in this country. Especially for expansion into distant offshore fisheries, we should investigate every possibility for improving design, materials, and equipment to cut vessel operating costs and increase productiveness.

FISH-FINDING EQUIPMENT

Echo sounders have greatly increased the navigating capacity and fish-locating ability of fishing craft (Hodgson, 1950). But these instruments were designed and built primarily for bottom sounding, and in most cases, they are not very efficient for locating fish.

Two important developments within the last five years are (1) cathode-ray tube presentation of echo signals on a radar-like screen, and (2) echo-ranging equipment, which permits the fisherman to scan the waters on both sides and in front of the vessel in addition to directly below (Hodgson and Fridricksson, 1955). Already there are several of the first-mentioned type of instruments and at least one of the latter on the market in this country.

Even though these instruments have been successful to a degree, they are still far from perfect for the job. Also, there is possibly as great a need for trained operators as for improved instruments. Like submarine-detecting sonar, these electronic fish-finders are complicated and sensitive instruments. Many hours of practice are required before the operator can use them properly and be sure of the identification of fish or other objects causing the echoes.

IMPROVEMENTS IN GEAR

There is a wide-open field for fishing gear improvement. In the last few years, with introduction of synthetics into net-making, some progress has been made. But there is probably no other basic industry in which changes in equipment have been so slow. This has been caused, at least in part, by our inability to observe the gear in action under water.

Recent developments in skin diving, underwater photography and underwater television offer the best chance we have had for studying gear in operation, as pointed out by Sand (1957). It is now possible to observe a trawl catching fish, analyze its weak points, notice how some of the fish escape, and then make changes in the design and method of operation to increase its productiveness.

In addition to opportunities for improving design, construction and operating methods, there is room for continued improvement in fishing gear materials and methods of preservation. If, through development of better net material or preservatives, one additional year could be added to the life of nets it would represent a great savings to fishermen.

Nylon and other sythetics have been widely successful in gill-net fisheries (Atton, 1955) but their use in seines and trawls has not been thoroughly tested.

Mechinization of fishing methods and gear offers another excellent opportunity for cutting operation costs. The new power block on the Pacific Coast has enabled salmon seiners to reduce their crews by two or three men while still making more sets per day (Anonymous, 1955b).

MIDWATER TRAWLING

United States catch statistics show that approximately 70 percent of our commercial fish catch is taken on or near the surface of the ocean and approximately 30 percent from the bottom. This leaves a vast volume of water in between which is virtually untouched and non-productive. The quantities of fish present in this midwater area are unknown. Only in the last decade with the advent of midwater trawling, principally in Europe and British Columbia, has any real progress been made in this direction (Barraclough and Johnson, 1956).

This new method of fishing requires years more research in various regions before we will know its full potential in developing the unutilized resources of the open ocean. Ultimate success will depend not only on proper gear design and operating methods, but also on development of better instruments and techniques for locating schools of fish in midwater, identifying them, and positioning the net at the proper depth for best catches (Richardson, 1957).

ELECTRICAL FISHING

Electrical fishing is still the big question mark in gear research and development. Two or three years ago it appeared well on its way to becoming a productive fish-producing method (Dickson, 1954). Europeans, particularly in Germany, made fantastic claims about future application of electricity to trawling, seining and trapping fish in the ocean. But there has been little or no recent substantiation of these claims.

It is probable that electrical fishing can be perfected for producing great volumes of fish only through considerable expenditures of research funds. However, if the demand for increased production becomes intense enough, such expenditures may be justified. Research should then be directed toward such methods as attracting fish to standard gear with electrical currents, herding them with electricity, and use of electrical attraction in combination with fish pumps.

FUTURE COURSE OF GEAR RESEARCH

Fishing gear research is not keeping up with research in other industries, and the United States is lagging behind some foreign nations which are active in this field.

If our fisheries are to keep up with other industries and meet foreign competition, there should be more attention given to *basic* research on gear design, construction and materials. Our technicians will need more funds, equipment and time. Supervisors and administrators, both in industry and government, must allow the scientists and technicians more latitude for *basic* studies and not demand immediate results in every instance. It must be recognized that in gear research, as in other fields, there will be failures as well as successes and that some long-range projects are necessary.

There should be an effort to assemble men who are particularly suited to gear research—inventors, machinists, engineers, men who can design and build things—preferably with experience or knowledge of the commerical fisheries.

Further, more new ideas should be tried instead of staying with accomplished designs or materials with the hope of attaining quick results. Why are all midwater trawls made square, with four equal sides? Because Robert Larsen, who invented the first practical midwater trawl, built a square one (Glanville, 1956). We do not know if this is the best design because no one has had time or money to conduct the numerous experiments necessary to determine what the proper design should be.

With all the tools and new equipment now available for underwater research, the future gear requirements of the fishing industry can be met. For best results, it will require close cooperation among the commercial fishermen and vessel operators, gear manufacturers, administrators and research workers in the field.

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Part 3

Symposium
on
Reservoir Management

FISHERIES PROBLEMS IN IMPOUNDED WATERS OF CALIFORNIA AND THE LOWER COLORADO RIVER

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Abstract

Doubling of the amount of impounded waters in California is in the foreseeable future. Basic climatology dictates winter and spring storage and summer and fall drawdowns, a feature common to far western impoundments. Most of these impoundments will support warm-water fisheries. Native fresh-water fish populations in California and the lower Colorado River have not adjusted to the combination of impoundment and predation by introduced warm-water sport species and often the introduced species have not maintained desirable population structures. The sunfishes frequently stunt and are believed to depress the bass populations. Extremely poor survival of bass-of-the-year is common. An unsatisfactory bass-of-the-year/forage ratio exists in the fall when the young bass turn to a fish diet. Food production is poor in the littoral zone because of water level fluctuation, but plankton production in open waters is usually adequate.

Over a period of years, following construction, the reservoirs experience a typical pattern of high initial fishing success, a sharp decrease, and then a gradual rise to a fishery somewhere near half the magnitude of the initial phase. The decrease is believed to be the result of the high initial fertility, characteristic of newly farmed lands, being leached out by repeated fluctuation. The readjustment of the fishery to a lower level is the result of its adjustment to the basic fertility of the basin. Management practices are based upon attempts to modify the decline and to maintain a fishery as close to that of the initial phase as possible.

Fertilization, in the farm pond sense, is not practical. The establishment of littoral zone cover crops that perpetuate themselves even though undergoing considerable periods of submersion is suggested. The modification of the use pattern and special construction features are useful but require constant vigilance by the fisheries agencies and the cooperation of construction and operation agencies. Population manipulation, principally through the use of rotenone, is a widely used management tool but is a negative approach that usually necessitates the impoundment being removed from the fishery for varying lengths of time. Modification of population structure by the introduction of the threadfin shad into the lower Colorado River as a forage species has met with apparent high success.

Introduction

In the Central Valley of California there are now 38 major storage reservoirs with a total capacity of 30,000,000 acre-feet. Five hundred miles of associated canals convey this stored water to various points of need. The California Water Plan envisions that in the future there will be 260 additional major reservoirs with an additional storage capacity of 60,000,000 acre-feet. At least 700 miles of new canals will be required. Nearly all of these impoundments will be suitable for warm-water fish, and in many instances streams which now support important salmonid fisheries will support fisheries for largemouth bass and associated warm-water species. Similar changes are now going on in some degree in nearly every far western state and it is likely that reservoirs and canals will exert increasing influence on our fisheries in the future. In California and the lower Colorado River virtually all the natural flow eventually will be under control. Only the high Sierra lakes and minor trout streams have any chance of remaining untouched. This discussion will be confined to warm-water fish problems and will not include trout and anadromous species.

Climatology of the Area

Climate dictates whether or not impoundments will be built, what kind they will be, and their use. The average annual normal rainfall in the Central Valley of California is about 13 inches and ranges from 24 inches at Chico in the north to 6 inches at Bakersfield in the south. About 90 percent of the annual rainfall occurs during the November-to-April period (Fig. 1). Several months in the summer are frequently without rainfall. Similar climatic conditions prevail along the lower Colorado River although here summer thunder showers occur. Normal annual precipitation along the lower Colorado River ranges from 3 to 6 inches. The seasonal distribution of rainfall in both areas dictates a general pattern of storage of winter and spring runoff. The use of the stored water (and draw-down pattern of the reservoir) depends upon the purpose of the impoundment but in nearly all reservoirs water levels are low in the fall. The basic hydrology involved is illustrated in Figures 1 and 2 which show precipitation and water diversion patterns for the Central Valley of California.

Types of Impoundments

There are four general types of impoundments in California or on the lower Colorado River in addition to associated canals.

COMPREHENSIVE POWER DEVELOPMENT RESERVOIR SYSTEMS

Comprehensive power development reservoir systems usually consist of a series of impoundments at high to moderate elevations. The connecting river is diverted through canals or tunnels from the afterbay of one powerhouse to the forebay of another. As little water as possible is left in the river channel unless it is to be used as a diversion canal or unless special releases have been negotiated or required for fish life and recreational use.

Levels of the uppermost reservoirs are subject to great seasonal fluctuation. Impoundments at lower elevations are subjected to sharp diurnal fluctuations because of uneven power demands. Streams between reservoirs, or what is left of them, warm up and large populations of rough fish, such as suckers, often develop and displace trout fisheries. However, smallmouth bass sometimes do well in such waters.

RESERVOIRS REGULATING IRRIGATION OR WATER DIVERSION

These are characterized by low level dams. The purpose of the impoundment is primarily regulation of water diversion and the lake behind the dam is usually quite small. Lake Havasu on the Colorado River is an exception for here power is also generated and a considerable lake has been created to provide the necessary head. Water passes through such reservoirs very rapidly; the level may fluctuate often and suddenly and the basic fertility of the basin thereby leached out.

Unless downstream water use or power demands require constant release,

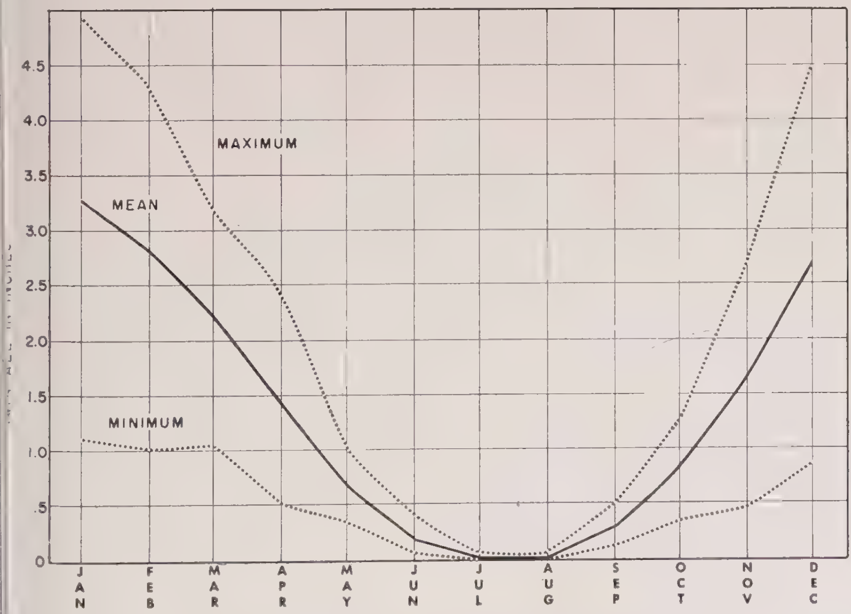

FIGURE 1.—Monthly rainfall pattern of the central valley of California. Data averaged from Climatological Data, Ann. Summary 1952, U. S. Dept. Comm. Wx. Bur. using five stations: Chico (82 years of record), Bakersfield (64 years), Fresno (75 years), Marysville (81 years), and Sacramento (104 years).

the river flow below the dam may at times be greatly reduced or entirely eliminated. Return irrigation water and seepage may create a much reduced flow some distance downstream from the dam. When the irrigation season is over the whole flow of the river may be released through the dam and the storage basin drained. This, together with fluctuations during the irrigation season, severely limits fish productivity. Plant growth is frequently lacking. However, in Lake Havasu, where the fluctuation is limited, extensive plant communities exist.

LARGE IRRIGATION IMPOUNDMENTS

Large irrigation impoundments such as Millerton Lake, Fresno and Madera Counties, California, usually rise in level in the spring at least until June and then decline until a combination of fall rain and lessened irrigation demand starts the level upward again. Monthly change in water

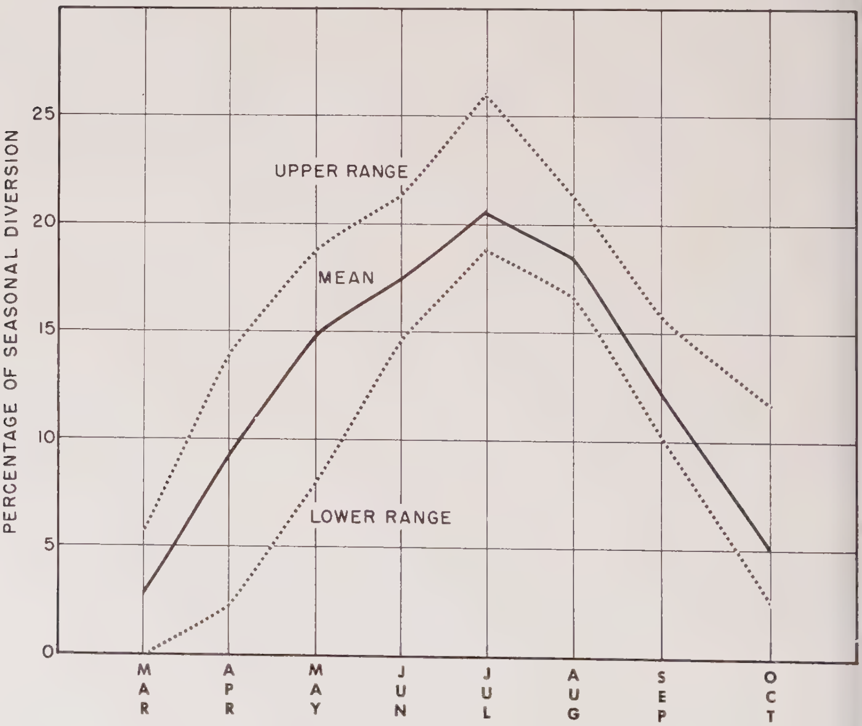

FIGURE 2.—Average monthly diversion in percent of seasonal total for Sacramento and San Joaquin Valley Streams, 1945 to 1954.

storage of Millerton Lake in 1954, not an unusual year, is shown in Table 1. At time of greatest drawdown in July and August the water level may drop as much as a foot per day. The water level fluctuates as much as 140 feet during the year and the lowest level is usually in the fall. This kind of usage creates a very unstable and sterile littoral zone after a few years of fluctuation. The surface waters of the open reservoir and littoral waters are warm and plankton production is fairly high. Because the outlet is sub-surface the surface waters, although lowered at a rapid rate, are frequently undisturbed.

TABLE 1.—*Change in water storage of Millerton Lake, California, 1954.*

Month	Acre-feet in Thousands[1]	
January	+ 20.7	
February	+ 42.9	
March	+ 65.7	
April	+ 137.8	
May	+ 68.8	Largemouth bass spawn from May 15 to June 15
June	— 38.8	
July	— 151.2	
August	— 139.4	
September	— 41.2	
October	+ 4.7	
November	+ 25.5	
December	+ 56.1	

[1] Storage = +; Draft = —.

MULTIPLE-PURPOSE IMPOUNDMENTS

Multiple purpose impoundments have complex operational schedules that usually include use for power, flood control, irrigation, navigation, and occasionally, salinity control. Shasta Lake on the upper Sacramento River is an example of this type. In spite of seasonal needs for irrigation and flood control and the irregular releases required for power, a regular flow is maintained downstream to control salinity of estuarial water and to aid navigation. Fluctuations in downstream flow are smoothed by the operation of a regulating dam at Keswick. Despite fluctuation, the surface waters of Shasta Lake are warm and relatively undisturbed because of the sub-surface outlet. Plankton production is moderately good but the littoral zone is leached of fertility by the seasonal fluctuation.

Canals and conduits associated with reservoirs are ordinarily not thought of as places to fish. They are usually lined with concrete or masonry and have swift flows. There is very little production of fish food. However, fish may be found wherever a projection or irregularity creates eddies and resting places. Fishing in canals is usually restricted because of danger to fishermen but some canals can and do furnish considerable fishing opportunity. Frequently canals are completely drained at regular intervals and this drainage, together with weed control and bottom improvement measures made to facilitate water movement, makes them very poor fish habitat.

Fish Populations of Reservoirs

The native fresh-water fish fauna of the Sacramento-San Joaquin River drainages includes one centrarchid, the Sacramento perch *(Archoplites interruptus),* tule perch *(Hysterocarpus traskii),* ten species of minnows, several suckers, cottids, and various resident and anadromous salmonids. Resident native fresh-water species total 23 (Murphy 1941; Shapovalov and Dill, 1950). An additional nine species were anadromous. This is a very limited fauna. By comparison at least 170 species of fishes are known from the Tennessee River and its tributaries (Kuhne, 1939).

The lower Colorado River originally had a small and highly specialized fauna of native fresh-water fish, in which the principal species were two large minnows, two suckers, and a species of cutthroat trout.

Present Fish Populations

In addition to the endemic fishes of the Sacramento-San Joaquin Rivers, 22 introduced species now occur and about the same number have been introduced into the lower Colorado River. Nearly all the introduced fish are sport or commercial species. The carp, an early introduction, has proven to be of little value. In recent years there has been an effort to introduce forage species, such as the fathead minnow, *Pimephales promelas* and the golden shiner, *Notemigonis crysoleucas.*

The principal introduced warm-water sport species are smallmouth bass, largemouth bass, channel catfish, white catfish, several bullheads, two crappies, and five sunfishes (Table 2).

Effect of Impoundment on Native Fishes

In the Sacramento-San Joaquin impoundments the ten native minnows have been variously affected. Where preyed upon by largemouth bass three species of minnows[1] exist but in reduced numbers. Three other species of minnows[2], principally small stream dwellers, disappear, and three species[3], lowland slough inhabitants, have not been regularly impounded. Suckers and some cottids are little affected by impoundment.

In the lower Colorado River, impoundment and control of the river has virtually eliminated the endemic minnows[4]. The humpback sucker *(Xyranchen texanus),* however, has been able to maintain itself in good numbers.

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[1] *Mylopharodon conocephalus, Lavinia exilicauda exilicauda* and *Ptychocheilus grandis.*
[2] *Hesperoleucus venustus, Hesperoleucus symmetricus symmetricus,* and *Rhinichthys osculus carringtonii.*
[3] *Siphateles bicolor formosus, Gila crassicauda,* and *Orthodon microlepidotus.*
[4] *Ptychocheilus lucius* and *Gila robusta elegans.*

TABLE 2.—*Occurrence of introduced warm-water sport fish of the Sacramento-San Joaquin Basin and the Lower Colorado River*[1]

Channel catfish	*Ictalurus punctatus*	X	X
White catfish	*Ictalurus catus*	X	
Brown bullhead	*Ameiurus nebulosus*	X	X
Black bullhead	*Ameiurus melas*	X	
Yellow bullhead	*Ameiurus natalis*	X	X
Smallmouth bass	*Micropterus dolomieu*	X	X[2]
Largemouth bass	*Micropterus salmoides*	X	X
Spotted bass	*Micropterus punctulatus*	X[2]	
Black crappie	*Pomoxis nigromaculatus*	X	X
White crappie	*Pomoxis annularis*	X	
Bluegill sunfish	*Lepomis macrochirus*	X	X
Green sunfish	*Lepomis cyanellus*	X	X
Warmouth	*Chaenobryttus coronarius*	X[2]	X[2]
Pumpkinseed	*Lepomis gibbosus*	X[2]	
Redear sunfish	*Lepomis microlophus*	X[2]	X
	Total	14	10

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[1]Does not include the anadromous striped bass *(Roccus saxatilis)* or the American shad *(Alosa sapidissima)*, found in the Sacramento-San Joaquin Basin.
[2]Of minor importance or recently introduced.

It therefore appears that the native forage species of streams in the areas under discussion are not able to maintain satisfactory populations in impounded waters. This is particularly true when predation by introduced species occurs. The endemic minnows that are able to maintain even moderate populations are usually too large for forage at the end of the first year of growth. It should be noted that several species of California cyprinids regularly attain lengths over 18 inches.

EFFECT OF IMPOUNDMENT UPON INTRODUCED SPECIES

The introduced species are all dependent upon the littoral zone at some stage in their life history. And, as previously stated, impoundment levels fluctuate. This fluctuation affects fish life by inhibition of food production in the littoral zone.

Lesser effects of water level fluctuation are destruction of spawning habitat, stranding of fish in pockets cut off by draw-down, and interference with spawning. It is interesting to note that, in California, fluctuation has never been shown to have caused a spawning failure of largemouth bass. Nests may be exposed but this species always seems to bring off a brood. Year class failures have been noted but none have been attributed directly to water level fluctuation.

Sampling of fish populations in impoundments by California workers has consistently shown poor forage fish-predator ratios for fish of the year.

A typical relationship of bass-of-the year to forage is shown in Figure 3. Forage species such as bluegills are frequently extremely abundant in fall but are too large to serve as forage for the bass-of-the-year. There is nearly always sufficient forage for adults. It appears that in the reservoirs populations of stunted sunfish may depress bass populations and there is evidence in similar instances (Swingle and Smith 1941, 1943) that bass eggs and fry are eaten by sunfishes. The possibility of the repressive factor suggested by Swingle (1956) operating to depress bass spawning has also been considered.

Differences in impoundment use, basic fertility of the water, conformation of the basin, climate, type of fish population, and angler use create many

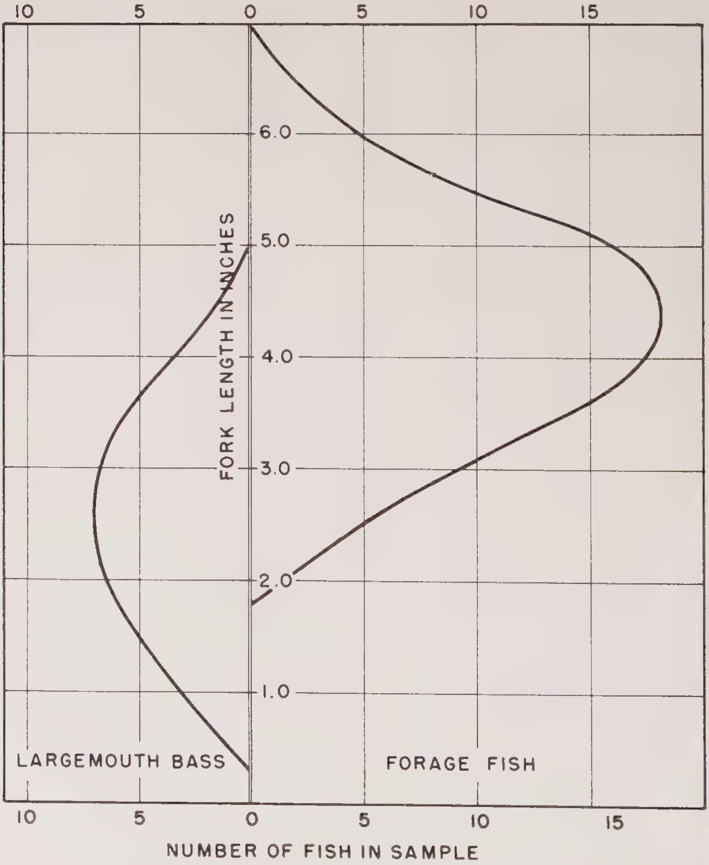

FIGURE 3.—A typical fall relationship between bass-of-the-year and forage fish in California.

different fish management situations. However, in all these situations it is difficult to establish and maintain satisfactory fish population structures if the littoral environment is unstable.

It is believed that the principal difficulty associated with water level fluctuations is lack of forage for bass-of-the-year when they turn to a fish diet late in the season at about three inches fork length. By that time the native minnows are too large and unless bluegill or other fish have a fall spawning the fingerling bass enter the fall without sufficient forage.

NEW-LAND EFFECT

M. M. Ellis (1936) pointed out that initial high productivity of newly impounded waters is often followed by a sharp decrease in productivity. This phenomenon has been observed in many impoundments since that time. The principal cause of initial rise followed by decline in production is believed to be use of and then decrease in initial soil fertility such as is observed when virgin lands are farmed for the first time: the so-called "new-land effect". In a new reservoir extensive areas of land are inundated on which is herbaceous vegetation, trees, accumulated animal wastes, and occasional village sites. The initial productivity is high and is usually evidenced by a phenomenal growth and survival of the fish. The peak of the high production phase may be reached two to five years after inundation but occasionally may occur sooner. Decline of the fishery may be rapid and in one or two years the fishing may be so poor that it causes public concern. Such a rapid decline is an indication that the high initial fertility is gone and that the populations of the fish and food organisms are becoming adjusted to the permanent basic fertility of the basin and nutrients in the runoff from the watershed. The fish population appears to have outgrown and "overgrazed" the original habitat. Repressive factors as suggested by Swingle *(op. cit.)* may also be operating.

Eschmeyer and Jones (1941) found that the rate of growth for six species of game fish was high in Norris Reservoir during the first three years of impoundment and a slowing of growth began in the fourth and fifth years of impoundment. This may be construed as an indication of the "new-land" effect.

The decline in the fishery often is followed by recovery and stabilization at a new and lower level. This may occur whether or not any special management has been applied. The length of time required for the adjustment of the fish population to the basic fertility of the basin and the use regime varies with the impoundment and the fish population level at which the adjustment stabilizes. In Millerton Lake this was about half the initial peak fishery. When fish population trends are evaluated by catch rates it is important to realize that catches fluctuate around a mean even in the years of high initial production. The status of a fishery, therefore, can be determined only on the basis of several years of creel census.

At Millerton Lake, California, creel census data for the period 1945-1952 (Abell and Fisher, 1953) document fishing trends in a new impoundment rather clearly (Figure 4). This reservoir came into existence in its present form in February 1944 when complete control of the river outlets was effected. A pond, varying in size, had been maintained behind the dam during the period of construction. This pond was heavily stocked with warm-water fish in 1941 and 1942. Occasional observations through 1941-44 showed a good fish population was being maintained but due to the war emergency this water was not opened for public fishing until 1945 (Dill, 1946). Initial catch per angler-day in 1945 was 5.92 fish of all species. Catch per angler-day increased to 7.01 fish in 1946 and then began a precipitous drop to a low of 0.70 fish in 1948. There was a slow undulating rise from that year until 1952 when the census was discontinued. During this period the catch rate ranged from 1.3 to 3.2 fish per angler-day.

The basic fish management problem in a new reservoir is to develop

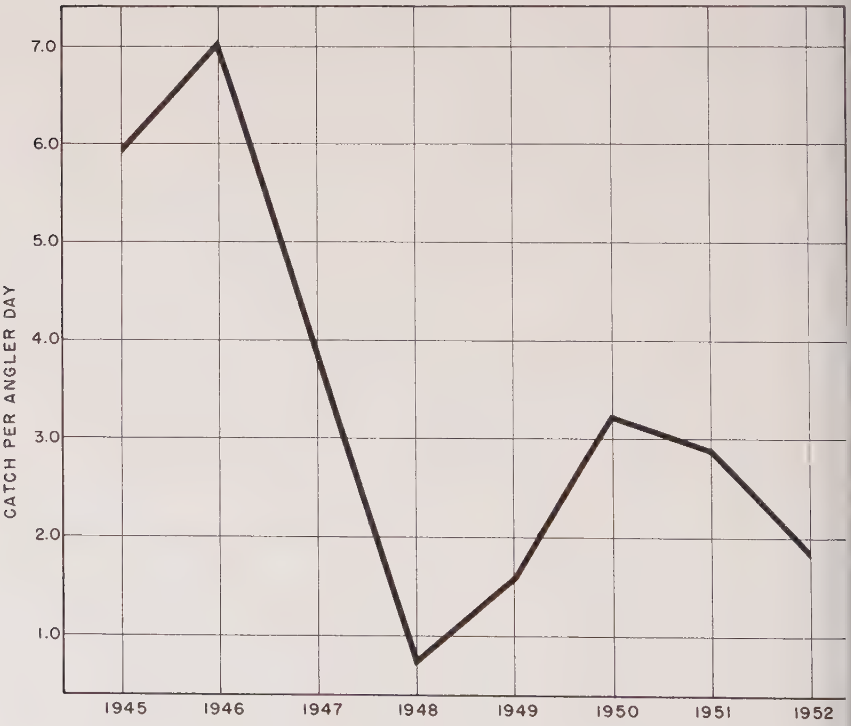

FIGURE 4.—Catch history of the Millerton Lake, Fresno and Madera counties California from 1945 to 1952

methods for decreasing the initial population decline and maintenance of a fluctuating population level near the optimum for the reservoir. Such a hypothetical flattening of production peaks and valleys is shown in Figure 5. The solid line represents the usual production history of new impoundments and the dotted line the desired pattern. Methods are also needed whereby the time and magnitude of the crash decline can be predicted so that management can be applied early enough to modify (if possible) population trends. There are several possibilities for accomplishing such modification.

Management Practices

Management practices having possibilities for smoothing fluctuations of fish populations in reservoirs and for increasing yields include fertilization, modification of reservoir use regime and population manipulation, either through removal or introduction of fish.

FERTILIZATION

Fertilization of entire reservoirs is expensive and results achieved would probably be of transitory value because of constant exchange of water. A cheaper and better approach is improving the fertility of the littoral area by establishing perennial cover plants able to survive inundation from fluctuating water levels. Bermuda grass, *Cynodon dactylon*, has prospects

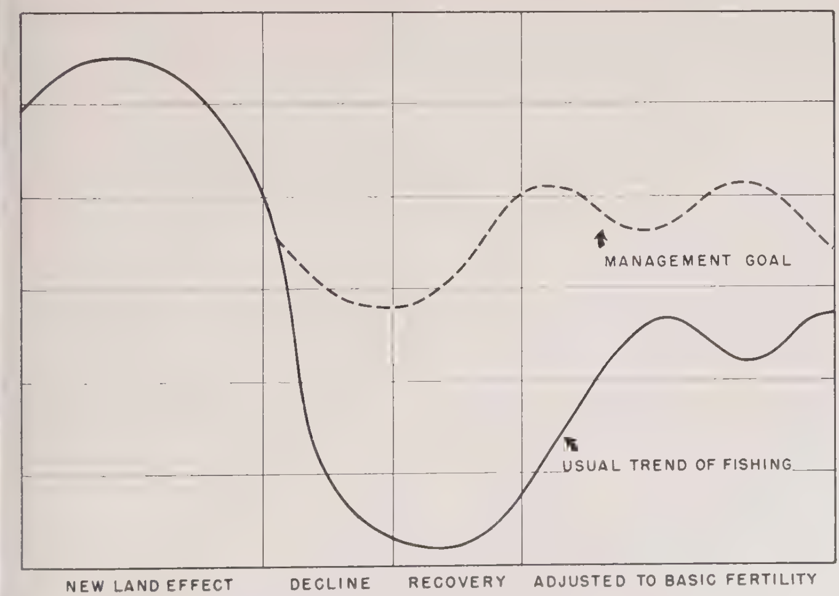

Figure 5.—History of a hypothetical impoundment fishery.

for this type of management. It has spread to nearly all suitable areas in Millerton Lake. The limiting factor in establishing the grass appears to be gradient. Its stolons have survived submersion to depths of 100 feet for as long as seven months. As the water recedes during draw-down the stolons send out shoots when still submerged several feet.

Where Bermuda grass was established barren bottom soils characteristic of unstable littoral areas affected by water level fluctuation were lacking or modified. The submerged mats of grass provided a substrate for many food organisms where previously there had been shifting sand and silt. If Bermuda grass is submerged each season the leaves and dead stems decay and liberate some nutrients into the water.

MODIFICATION OF THE RESERVOIR USE

When the needs of fish life are adequately demonstrated to the operating agency, it is often possible to obtain operational use modifications of benefit to fish providing they do not interfere with the original purpose of the impoundment.

For example, elimination of periodic draining of powerhouse forebays and afterbays or the complete annual release of water from irrigation diversion impoundments would provide more stable environments for fish. Similarly, if water were held the year-around fish would be benefited and more fishing provided.

Modifications in plans for construction and operation of impoundments and canals could provide for some dead storage that would create areas in which fish could survive. Modification of impoundments and their use can, however, be only a partial answer. In most instances, full advantage is now being taken of such modifications. Fisheries agencies must be alert when reservoirs and diversions are planned so that features of benefit to fish can be included.

POPULATION MANIPULATION BY USE OF FISH POISONS

Population manipulation normally entails removing all or part of a fish population and then restocking. In California, reservoirs have been treated with fish poisons to remove carp or fishes that are stunted or otherwise undesirable. Pre-impoundment treatment of entire stream drainages to remove extensive rough fish populations has been only moderately successful. In nearly every instance the fish kill has been incomplete. Such poisoning does, however, give planted sport fish a chance to become established before the rough fish, such as carp, recover. Use of rotenone and other poisons is perhaps our most important management tool for manipulation of fish populations. However, it represents a negative approach, since the waters poisoned are removed from production for a time. Effects of poisoning are temporary and leave the basic problem of low productivity unsolved.

Population Manipulation by the Introduction of Fish

Attempts to establish fathead minnows, golden shiners, and plains red shiners *(Notropis lutrensis lutrensis)* as forage species in Central California impoundments have not produced desirable results. Because of predation, especially from black bass, the fathead minnow has been unable to maintain itself in populations of satisfactory size into the fall. Similar results have been had with the golden shiner. In addition there has been poor survival where infestations of the parasitic crustacean, *Lernea carrassii* are high. The plains red shiner has not become established outside of Southern California but in this area it is a useful forage fish.

As a result of a biological survey of the lower Colorado River from Lake Mead to the Mexican border, initiated by the States of Arizona, California and Nevada in 1950, it was concluded that a forage fish was needed in this river that would:

1. . . . not be tied to the littoral zone during any part of its life history;
2. . . . utilize plankton in the open waters;
3. . . . not compete with the sport fish at any time during its life history;
4. . . . never grow out of the forage class;
5. . . . be acceptable to sport fish as forage;
6. . . . have an extended spawning period or a fall spawning so that small fish would be available to bass-of-the-year.

Such a fish was also needed in the Central Valley impoundments of California.

For a time the gizzard shad *(Dorosoma cepedianum)* was considered. It was found, however, to have too many undesirable characteristics. The late Dr. R. W. Eschmeyer suggested that a little-known relative of this fish, the threadfin shad *(Dorosoma petenensis atchafalayae)*, might satisfy the need. After review of the habits of this fish in its native waters it was judged suitable and a brood stock was procured from the Tennessee River in November, 1953. These fish successfully reproduced in brood ponds in San Diego County and their progeny, 1,020 fish of the year varying from 1.2 to 3.4 inches fork length, were planted in Lake Havasu in November, 1954 and March, 1955. By September, 1955 threadfin shad were reported present in large numbers in irrigation canals east of Yuma, Arizona; in the Brawley, California, water-supply settling basins; in irrigation canals near the Imperial Wildlife Refuge, California; and in the Salton Sea. A one-acre cove in Lake Havasu was poisoned with rotenone in September 1955 and 300,000 to 500,000 shad were estimated to have been killed.

A study of the value of the threadfin shad as a forage species was started in 1956, and although still incomplete the introduction appears to have chieved the desired results. There has been no instance of threadfin shad growing out of the forage class, competing with sport species, or overpopulating. There is good evidence of accelated growth and increased survival in the sport fish that utilize shad. There is little evidence that the channel catfish population has been helped.

However, although to date the threadfin shad has been useful, there is enough inherent danger in the introduction of exotic species for this phase of management to be entered upon with caution.

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FISHERY MANAGEMENT PROBLEMS AND POSSIBILITIES ON LARGE SOUTHEASTERN RESERVOIRS

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ABSTRACT

Principal problems concerning the fisheries of large reservoirs in the Southeast are: inefficient and highly selective exploitation of fish stocks, and protection and reclamation of damaged or threatened fisheries in tailwaters and tributary streams. Seven mainstream reservoirs on which data are available support an average angling pressure of 4.9 trips per acre per year and an average catch of 16 pounds of sport fish and 6 pounds of food fish. Commercial take is 7 pounds per acre. The rate of catch of sport fish, based upon tag returns, is only 3 percent. Sixteen storage reservoirs support an average angling pressure of 5.0 trips per acre per year and an average catch of 13 pounds of sport fish and 1 pound of food fish. Commercial catch is of no significance. Average rate of catch of sport fish is 17 percent of the catchable population. Fish population studies indicate that there are twice as many sport fish and four times as many food fish in mainstream than there are in storage reservoirs.

Some reservoirs produce harmful effects downstream. Discharges of cold water may seriously reduce fishery values in tailwaters and downstream impoundments. Furthermore, migration of non-sport fish from reservoirs into tributary streams may reduce fishery values there.

In recognition of these problems, the development and application of sound management procedures may be accomplished by controlling species composition and availability of fish through water level control, timber clearing, application of selective toxicants, commercial fishing, introduction of new fish species, and the management of tailwaters and tributaries. Extended research and interagency cooperation are necessary to properly develop and apply sound management. Promotion of angling and regulation of the fishery may best be realized by providing adequate fishing facilities, elimination of certain restricted areas, and in some cases revision of laws and regulations. Biologists must not only meet the present demands for improved sport fishing but must also balance fish yield by increasing the use of food fish by sport and commercial operations.

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INTRODUCTION

The demands for flood control, hydroelectric power, and navigation have led to the construction of many reservoirs in the southeastern United States.[2] There are presently 86 large[3] reservoirs totalling more than 2 million acres in this area (Thomas and Harbuck, 1956). The rate of construction is indicated by the 71-percent increase in their number since 1947. The U. S. Army Corps of Engineers water-control program and applications to the Federal Power Commission by private power companies for licenses to construct dams point toward a continued high rate of construction.

The creation of fishery values was not an important consideration in the construction of these impoundments. They have, nevertheless, provided extensive new fishing areas, the values of which have far outweighed the injury to or destruction of a few cherished old ones. Not only has sport fishing become popular with local inhabitants; the tourist trade has added enormously to the economic welfare of the region.

The management of these new fisheries and the lessening of loss from injury to old ones offer numerous and peculiar problems. Difficulties are rendered more severe by a number of special circumstances. Construction of these reservoirs created not only new fisheries but also new and special types of environment about which little was known. Fishery biologists and administrators thus have been without the backlog of scientific literature and administrative precedent that usually can assist so greatly in the establishment of a new program. Rather, they have had deliberately to ignore much that has been learned in other areas and embark on a pioneer program of their own. This venture had to be started with the limited, sometimes ill-trained, and always underpaid staffs characteristic of areas in which fishing previously had been of small consequence, and in which management consisted entirely of enforcement of laws that had little rational basis. It is not urprising that early advances in the understanding of reservoir fisheries were slow and halting. It is gratifying that such fine progress has been made and that the outlook for the future is good.

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[2] Here considered to include the States of Maryland, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Arkansas.

[3] In this paper only those impoundments with a maximum surface area of at least 1,000 acres are considered. Lowhead reservoirs of Florida and Louisiana, which are actually stabilized lakes, are excluded.

Even though accomplishments to date are trivial in comparison to that which remains to be done, much has been learned about research and management on reservoirs of the Southeast. It appears timely now to undertake an appraisal of the situation—to review progress up to this time and to speculate as to the implications for the planning of future activities.

FISHES OF SOUTHEASTERN RESERVOIRS

In later discussions references are made repeatedly to certain species and groups of species. To make certain the identity of the fishes and define arbitrary groupings that are employed, the following list of common and scientific names of the principal fishes has been prepared.

SPORT FISH (GAME FISH)

Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieu*
Spotted bass	*Micropterus punctulatus*
Walleye	*Stizostedion vitreum*
Sauger	*Stizostedion canadense*
Striped bass	*Roccus saxatilis*
White bass	*Roccus chrysops*
Muskellunge	*Esox masquinongy*
Rainbow trout	*Salmo gairdneri*

SPORT FISH (PAN FISH)

Black crappie	*Pomoxis nigromaculatus*
White crappie	*Pomoxis annularis*
Rock bass	*Ambloplites rupestris*
Bluegill	*Lepomis macrochirus*
Longear sunfish	*Lepomis megalotis*
Warmouth	*Chaenobryttus coronarius*

FOOD FISH

Carp	*Cyprinus carpio*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*Ictiobus cyprinella*

Channel catfish	*Ictalurus punctatus*
Blue catfish	*Ictalurus furcatus*
White catfish	*Ictalurus catus*
Flathead catfish	*Pilodictis olivaris*
Paddlefish	*Polyodon spathula*
Sturgeon	*Acipenser fulvescens*
Fresh-water drum	*Aplodinotus grunniens*
Redhorse	*Moxostoma spp.*
Bullhead	*Ictalurus spp.*

FORAGE FISH

Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Signalosa petenensis*

OTHER SPECIES

Skipjack	*Alosa chrysochloris*
Longnose gar	*Lepisosteus osseus*
Mooneye	*Hiodon tergisus*
Goldeye	*Hiodon alosoides*

Types of Impoundments

Reservoirs in the Southeast are generally classified into four groups according to their principal use or location — flood control, power, storage, and mainstream reservoirs. Although most, other than flood control reservoirs, are in fact multiple-purpose impoundments, this partly-arbitrary classification adds considerably in the understanding of the variety of impoundments. In the consideration of fishery problems, all reservoir groups other than mainstream reservoirs may be combined and are referred to in the text as storage reservoirs.

FLOOD-CONTROL RESERVOIRS

The Southeast has seven single-purpose flood-control reservoirs with a total area of 217,000 acres (Table 1). Their average area is 31,000 acres and the mean depth is 22 feet. Surface area, however, is usually about ¼ to ½ of maximum during much of the major fishing period. All of these reservoirs are located on relatively small streams and they may be drawn down to 7 percent of their maximum capacity. Water levels are highest during months of heavy rain, February through May, and are lowest in September and October.

Water is discharged through conduits near the bottom of the reservoir; rarely does water pour over the spillway. The reservoirs may be turbid during the rainy season but usually they are clear (turbidity less than 10 p.p.m.).

TABLE 1.—*Physical descriptions of four types of southeastern reservoirs over 1,000 acres in area.*

Item	Type of reservoir			
	Flood-control	Power	Storage	Mainstream
Number	7	43	22	14
Surface area (acres)[1]				
Combined reservoirs	217,000	300,000	681,000	811,000
Largest reservoir	64,000	38,000	71,000	261,000
Average area	31,000	7,000	31,000	58,000
Mean depth (feet)	22	31	57	20
Percentage of water volume in dead storage[2]	7	40	30	61

[1] Acreages and depths based upon spillway pool levels.
[2] Based upon absolute minimum water levels.

POWER RESERVOIRS

The 43 southeastern power reservoirs at spillway level have a total of 300,000 acres. The average area is 7,000 acres and the mean depth is 31 feet. These reservoirs are located mostly on tributary streams. Water levels are usually highest in late winter and early spring. They are not lowered excessively at other times because of the need for sufficient head to generate electricity efficiently. On occasion these reservoirs may be drawn down to about 40 percent of maximum capacity.

Water is drawn through turbines at the base of the dams. Surplus water frequently passes over the spillway for short periods during rainy seasons. Reservoir waters are usually clear except after heavy rains.

STORAGE RESERVOIRS

The 22 storage reservoirs at spillway level have a total area of 681,000 acres. The average reservoir area is 31,000 acres and the mean depth is 57 feet. Primary purposes of these reservoirs are flood control and power. Water levels are high in the spring and low in the fall. Volume may be reduced to about 30 percent of maximum.

Water is drawn through turbines at the base of the dam and rarely passes over the spillway. Reservoirs of this type are usually clear except immediately following heavy rains.

MAINSTREAM RESERVOIRS

The 14 mainstream reservoirs at spillway level have a total area of 811,000 acres. The average reservoir area is 58,000 acres and the mean depth is 20 feet. They are used primarily for navigation, flood control, and power.

All are located on large rivers.

Except during flood periods or extreme draughts water levels remain relatively stable. Volume may be reduced to about 60 percent of maximum during operations.

Water is drawn through turbines at the base of the dams or through locks for navigation. Large volumes usually flow over the spillways during the late winter and spring. Reservoir waters may be relatively turbid for several months.

Principal differences among the types of reservoirs other than those already listed are: the relatively greater rate of flow through the mainstream reservoirs; construction of mainstream reservoirs in series to facilitate navigation (particularly on the Cumberland and Tennessee Rivers); thermal stratification to a much greater extent in storage and power reservoirs than in other types (Wiebe, 1940); limited shoreline development in mainstream impoundments (49 acres of water per mile of shoreline in mainstream reservoirs, 65 acres per mile in storage reservoirs).

MAJOR PROBLEMS OF RESERVOIR FISHERIES

The correction of the presently inefficient and highly selective exploitation of fish stocks in the reservoirs proper and the protection and reclamation of damaged or threatened fisheries in tailwaters and tributary streams offer the two most immediate and pressing problems in the development of a research and management program in the Southeast. Other problems exist, to be sure—some of them are mentioned in later discussions—but any long-term programs directed toward the development of truly scientific management must be concentrated on these two.

FISH PRODUCTION OF RESERVOIRS IN RELATION TO STOCK

Fish population studies although individually subject to bias, collectively offer useful indices to population composition. Stocks of the southeastern reservoirs have been sampled with gill and trammel nets, seines, various types of traps, and with the use of rotenone. Since the latter appears to be the most dependable single method and one in which sampling errors are generally comparable between reservoirs, records of fish populations were determined from collections by this method. The pounds of fish recovered per acre do not, however, necessarily represent standing crops; efficiency of recovery varies according to local circumstances.

The average recoveries of 146 and 354 pounds of fish per acre from storage and mainstream reservoirs, respectively, suggest that the latter are by far the more productive of fish (Table 2). Sport fish are about 2½ times more abundant in mainstream reservoirs than in storage reservoirs and food fish about four times more abundant. The percentage of weight of large fish was determined in two storage reservoirs where 42 percent of the weight of sport fish sampled and 73 percent of the food fish were of angling size.[4]

TABLE 2.—*A comparison of average fish population composition and fish catch from 6 mainstream and 9 storage reservoirs in the Southeast*[1]

Item	Type of reservoir	
	Storage[2]	Mainstream
Pounds of fish per acre sampled	146	354
Percentage of fish composition by weight		
Sport	23	24
Food	26	40
Forage	41	25
Other	10	11
Angling catch (pounds) per acre per year		
Sport	13	16
Food	1	6
Commercial take (pounds per acre per year)	...	7
Total pounds of fish taken per acre per year	14	29

[1] Data from: Carter (1954, 1955, 1957); F-2-R Job Completion Report, Tennessee Game and Fish Commission, unpublished; Fetterolf (1955); Swingle (1954); Eschmeyer, Manges, and Haslbauer (1946); Tarzwell (1941, 1945); Eschmeyer and Tarzwell (1941); Chance and Miller (1952).
[2] Includes storage, flood control, and power reservoirs.

Rates of exploitation in the two groups of reservoirs are decidedly unequal. The annual removal of 13 and 16 pounds of sport fish per acre from storage and mainstream reservoirs, respectively, indicates that sport fish are utilized to a greater extent in storage reservoirs. Food fish in storage reservoirs add 1 pound of fish per acre yearly to the catch by angling. Since commercial fishing is usually prohibited, greatly restricted, or inefficient, this fishery makes only a small contribution to the total take of fish.

On mainstream reservoirs food fish add 6 pounds of fish per acre yearly to the catch of anglers, and provide the entire 7 pounds per acre of commercial catch. This total of 13 pounds of fish accounts for most of the 15-pound difference in the annual fish yield per acre between the two types of reservoirs (Table 2).

Fishing pressure was similar on the two groups of reservoirs—5.0 and 4.9 fishing trips per acre annually (Table 3). The average weight of fish per trip was 2.8 from storage and 4.4 pounds from mainstream reservoirs.

The rate of cropping as indicated by returns of tagged sport fish (principally the black basses and black and white crappie) was 17 percent of the catchable-sized fish on storage reservoirs and only 3 percent on mainstream reservoirs. These rates give further evidence of low level of exploitation of sport fish in mainstream impoundments.

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[4] F-2-R, Job Completion Report, Tennessee Game and Fish Commission, unpublished.

TABLE 3.—*Comparison of sport fisheries on 6 mainstream and 11 storage reservoirs in the Southeast*[1]

Item	Type of reservoir	
	Storage[2]	Mainstream
Fishing trips per acre per year	5.0	4.9
Pounds of fish per trip	2.8	4.4
Average weight of each fish (pounds)	0.8	0.9
Yearly removal of fish (pounds per acre)	14	22
Rate of cropping[3]	17	3

[1] Based upon studies by Elser and Van Deusen (1954); Fetterolf (1955); Tarzwell (1945); Eschmeyer, Manges, and Haslbauer (1946); Carter (1954, 1955, 1957); Eschmeyer and Tarzwell (1941); Tarzwell (1941); Chance (1955); Miller (1951); Manges (1950); F-2-R Job Completion Report, Tennessee Game and Fish Commission, unpublished.

[2] Includes storage, flood-control, and power reservoirs.

[3] Percentage returns of tagged fish of catchable size.

The smallmouth, largemouth, and spotted basses represent about 47 percent of the fish taken by angling from storage reservoirs (Table 4). The annual rate of cropping of these fish was 30 percent. This finding proves that angling on storage reservoirs is highly selective. Black and white crappie represented 27 percent of the fish catch and the rate of cropping was 20 percent. The black basses, although the most abundant group of fish in catches from mainstream reservoirs represented only 13 percent of the angling catch, and the rate of cropping was 15 percent. Crappie represented 24 percent of the catch and the rate of cropping was 11 percent.

TABLE 4.—*Comparison of average catch composition and rate of cropping of two principal types of sport fish from 4 storage and 4 mainstream reservoirs*[1]

Item	Type of reservoir	
	Storage[2]	Mainstream
Black basses		
Percentage of angling catch	47	13
Rate of cropping	30	15
White and black crappie		
Percentage of angling catch	27	24
Rate of cropping	20	11

[1] Data from: Fetterolf (1955); Eschmeyer and Tarzwell (1941); Tarzwell (1941); Carter (1957); F-2-R Job Completion Report, Tennessee Game and Fish Commission, unpublished.

[2] Includes storage, flood control, and power reservoirs.

Although angling and commercial fishing take 13 pounds of food fish per acre annually, TVA biologists have concluded that catches of food fish could probably be increased 5-fold without seriously reducing the catch per unit of commercial fishing gear (Tarzwell, 1945).

This information on the fish populations and fisheries not only shows differences between the two types of reservoirs, but clearly demonstrates that the fishery resources are greatly underexploited. On the average, angling takes only 2 percent of the weight of fish from storage reservoirs annually. The fact that sport-fishing regulations on these waters have been liberalized emphasizes the inefficiency of sport fishing as a method of cropping. Food and panfish species offer the best opportunity for expanded utilization.

SPECIAL PROBLEMS OF TAILWATERS AND TRIBUTARIES

The drawing of waters from the cold depths of the reservoirs and discharging them directly into rivers or reservoirs below probably represents the biggest threat to the fishery potential of the Southeast. "Reservoir" management must then include special consideration of downstream (tailwater) areas. Usually waters discharged below mainstream and flood-control reservoirs are warm. Below storage reservoirs, and to a lesser extent on power reservoirs, most water discharges are cold (less than 70° F.)

All storage and power reservoirs in the Southeast are located on warm-water streams and the discharge of cold water below the dams accordingly has had profound effects on the fish populations. Where reservoirs such as Bull Shoals Dam in Arkansas and Lake Cumberland in Kentucky, are on large streams, warm-water fisheries may be eliminated for distances up to 200 miles.

Excellent put-and-take trout fisheries have been established below many storage reservoirs. Seldom do these fisheries extend beyond 15 miles below the dam even though conditions may appear to be suitable for trout farther downstream. In Tennessee, trout fisheries have been established below 10 storage reservoirs (Pfitzer, 1953). Although these trout fisheries are valuable in many ways, they solve only a small part of the problem created by cold-water discharges. Many miles of streams and upper embayments of some reservoirs support adequately neither a warm- nor cold-water fishery.

When dams are constructed in a series along a stream, discharges of cold water from upstream reservoirs may damage seriously warm-water fish populations in downstream impoundments.

In two localities, below Center Hill Dam in Tennessee and Lake Cumberland Dam in Kentucky, discharges from the depths of the reservoir are not productive of aquatic organisms in any numbers for 20 miles below the dam. Reasons for this situation have not yet been determined. Waters discharged below Roanoak Rapids Reservoir in North Carolina have sometimes been found to lack adequate oxygen to support fish life.

Another problem is the excessively high discharge from some storage and power reservoirs that makes effective fishing nearly impossible. At other localities, water discharges may be entirely shut off long enough for the cold waters downstream to become warm.

Fish populations of streams tributary to reservoirs likewise have been affected adversely by impoundment. For example, one formerly excellent 35-mile sport-fishing stream in Tennessee was found to contain a fish population, consisting of 75 percent large non-sport fish by weight, that had migrated from a downstream reservoir.[5] These fish were principally carp, smallmouth buffalo, freshwater drum, and gizzard shad. Except for the extreme lower regions of the stream, there was little evidence that sport fish migrated upstream from the reservoir. Investigations in many other Tennessee streams revealed similar influxes of non-sport fish from reservoirs (Ruhr, 1957).

Fishermen and biologists in the Southeast are increasingly concerned about the impoundment of high-value smallmouth bass streams. The total mileage of streams producing good warm-water sport fishing is being reduced rapidly. Although economic considerations may force the impoundment of many more of these streams, some natural streams with high fishery values should be preserved.

DEVELOPMENT AND APPLICATION OF SOUND MANAGEMENT PROCEDURES

A sound, well-rounded program for the betterment of reservoir fisheries must be developed along several lines. Every known practicable method for the improvement of fish stocks and their utilization should be tested and a constant search prosecuted for new techniques. Fish populations should be managed to give greater productivity, improve species composition, and increase availability. In many reservoirs commercial fishing may prove an effective and profitable tool for population control. Sport fishermen should be educated into more effective methods of fishing and into the acceptance of a wider range of species. The intensity of angling should be increased through the provision of more and better facilities.

If this program is to prove effective it must have the support of continued research—research to test procedures, research to find new procedures, research to learn better the biological processes whereby fish are produced.

If management is to be placed on a sound basis it should be borne in mind that the chemical and physical characteristics which determine reservoir productivity are largely the interaction of: the configuration of the basin; the age of the reservoir; the quality and quantity of inflowing water; and the type of water discharge. Sound management on individual reservoirs calls for familiarity with their specific problems and knowledge of the results of management and research on other similar waters.

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[5] Parsons, John W. 1953. A preliminary report on the fish population studies of Obed and Emory Rivers, Tennessee, 12 pp. [Mimeographed]

The question of inefficient utilization of reservoir fishery resources has but one answer—that of increasing fish yield. Attempts to achieve increased yield should not, however, seriously reduce the pleasures of sport fishing. The recognized approaches to increasing fish yield from a reservoir are many. Those considered most important are: increasing the numbers or availability of catchable fish; managing the fishing and fishermen; and protecting or reclaiming fisheries in waters affected by reservoirs.

CONTROL OF SPECIES COMPOSITION AND AVAILABILITY OF FISH

WATER-LEVEL CONTROL

Water-level fluctuation in the multi-purpose reservoirs of the Southeast is controlled for three principal purposes: power, navigation, and flood control. Fish populations and angling success may be damaged or improved as a result of these regulated water-level fluctuations, depending upon particular conditions and the type of reservoir. Water-level control for fishery management may be compatible with or opposed to water levels regulated for purposes of the reservoir project. Since fishery management likely would require modification of standard patterns of water-level fluctuation, recommendations must be balanced with other water uses (Parsons and Crossman, 1955).

For maximum flood control and power benefits, in most reservoirs, near-maximum levels are reached in late winter and spring and minimum water levels in late fall and early winter. Water levels may fluctuate annually as little as 4 feet or as much as 150 feet, depending upon the reservoir usage. Water-level regulation for mosquito control, practiced mostly on TVA waters, consists of periodic lowering and raising the levels about 1 foot during the summer.

Fishermen and boat-dock operators on many southeastern reservoirs contend that fishing success falls off during rapid lowering of the reservoir. Most reservoirs have the greatest fishing pressure and fish catch during April, May, and June.[6] This season contributes nearly one-half of the total annual yield of sport fish. Severe drawdowns during that time could, then, materially reduce the total annual catch. On the other hand, stabilization of water levels over the same period may improve fishing.

In some reservoirs, rapid spring drawdowns expose black bass nests or subject them to shallow-water conditions. In either event, the adult bass desert the exposed nests. Without question many bass eggs are lost during severe drawdowns; usually, however, more than ample young bass are

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Eschmeyer and Tarzwell, 1939; F-2-R Job Completion Report, Tennessee Game and Fish Commission (unpublished).

produced despite the loss of some eggs. Where bass are scarce or lack of spawning areas limits reproduction, water-level stabilization in the spring for increasing the number of young bass hatched may be necessary.

Young largemouth bass of southeastern reservoirs feed principally on young gizzard and threadfin shad and/or sunfishes. When shad spawn late or bass spawn earlier than usual, the young bass are able to eat the young shad throughout a portion of the year. When bass spawn late, the shad may immediately outgrow the young bass and therefore not be available. Under such conditions, the young bass must depend on young sunfishes as their main food. Rapid drawdowns in late spring and early summer, may so reduce the production of small sunfishes as ultimately to reduce the survival and growth of the young bass. Where low production of young bluegills and sunfish may limit a bass or bluegill fishery, water-level stabilization during the late spring and summer should be considered. Several states, including California and Nevada, have stocked threadfin shad in reservoirs where fluctuating water levels have seriously reduced the production of small bluegills as forage, and thereby exposed young bass to excessive cannabalism (Kimsey, 1954). On the other hand, where sunfishes may be overly abundant, rapid draw-down may be exercised as a method of control.

Fluctuation of the water level offers a reliable method for the reduction of a carp population in one storage reservoir in Tennessee.[7] Carp spawn in this impoundment in May and early June usually in water less than 2 feet deep. The eggs adhere to all types of bottom materials, particularly land vegetation that had grown during the previous summer's drawdown. Here a 2-foot drawdown would destroy carp eggs. This type of carp control should not be undertaken, however, until the need for it is established. For example, studies in the reservoir just mentioned proved that the carp was not detrimental to the sport-fish population. The carp fed mostly on detritus; large numbers of bluegill followed the carp during the spawning period and fed heavily on carp eggs. Later they consumed carp fry. Furthermore, the bluegill concentration along the shore lines during that time resulted in especially good catches of this fish. Similar conditions may exist in other impoundments.

Some fishery workers in the past have assumed that the low water volumes resulting from heavy summer and fall drawdowns may have the following effects: improve the availability of sport and commercial fish; increase the availability of forage and other small fish to predators; increase availability of fertilizing elements in the soils of exposed and dried mud flats at later increases of water level; allow growth of land vegetation on the exposed reservoir basin during low water to provide fertilizer and fish cover at higher water levels; and expand the fish population as a result of the great increase in water volume in the spring. These considerations have been sufficiently discussed by Wood (1951) and Ellis (1936). In most waters the extent to which these alleged benefits actually accrue can only be conjectured. The Arkansas Game and Fish Commission, however, increased commercial catches by lowering fall water levels on flood-control reservoirs (Hulsey, 1956).

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[7] F-2-R, Job Completion Report, Tennessee Game and Fish Commission, (unpublished).

In the uses made of water-level control in fishery management, certain basic considerations apply to each of the several types of reservoirs. Water-level fluctuations for project purposes on most mainstream, power, and storage reservoirs appear to be reasonably compatible with fish production and catch. Modification of water-level fluctuations for fish on mainstream and power reservoirs may result in only limited fishery benefits. However, water-level fluctuations exceeding 2 feet per month during spring and early summer should be avoided on most storage reservoirs whenever possible.

The excessive water-level fluctuations of single-purpose flood-control reservoirs create many fishery problems. Since the flood-control function cannot be compromised greatly, recommendations for modification of water-level stages must be reasonable. The greatest opportunity for development of fisheries on flood-control reservoirs, lies in establishing a larger seasonal conservation pool to provide additional storage capacity. These pools during summer should constitute at least one-fourth of the total pool area at spillway level. Waters can then be lowered in the fall to increase the reservoir capacity for flood control prior to the winter rains. Further reduction of pool levels will provide increased opportunities for commercial fishing; however, the effects of these drawdowns upon sport fish are not well understood.

Although certain applications of water-level manipulation to management can be termed general, individual reservoirs will require close investigation before maximum benefits through this method can be realized.

TIMBER CLEARING

The effects of disposition of timber in reservoir basins on fisheries long has been a most controversial subject. Fishery workers themselves have various opinions on this subject but they generally agree that timber left standing in deeper portions of a reservoir is not harmful and that parcels of timber in the zone of water-level fluctuation along the shorelines will attract and concentrate sport fish for easier catching.

Principal controversy arises as to where and how much timber should be left along the shorelines. This issue is also of considerable economic importance in view of the costs of timber clearing.

It has been conjectured that extensive timber in a reservoir basin may result in harmful chemical combination in the nutrient materials. Indeed, variations in the amount of timber may account for variations in the quality of water discharged downstream from reservoir depths.

There is every reason to believe that the proper disposition and use of standing timber may be a means of increasing fishing success. The effects of various clearing procedures upon the catch of fish must be learned before selective clearing can be adopted as an effective fishery-management tool. Experiments of this type are expected to be made in Table Rock Reservoir in Missouri, and Hartwell Reservoir, Georgia and South Carolina.

BRUSH SHELTERS

Fishermen and dock owners in the Southeast generally favor the installation of brush shelters in large reservoirs but most state conservation agencies consider them ineffective for the improvement of fishing. At the suggestion of the U. S. Fish and Wildlife Service, brush shelters have been constructed in several reservoirs by the Corps of Engineers during timber-clearing before impoundage. The Tennessee Game and Fish Commission is now experimenting with brush shelters on two large reservoirs.

Most "brush shelters" in the Southeast are actually two or three crossed logs or trees cabled together and attached to the reservoir bottom. It has become increasingly evident that logs serve better than brush to attract catchable sport fish. If shelters prove desirable, selective timber-clearing may eliminate any need for brush-shelter programs in new impoundments.

SELECTIVE KILLING OF FISH

The value of selective killing of gizzard shad with rotenone is a matter of controversy. Many tons of shad have been killed by this method. The technique was originally designed to provide more food and space for fish such as bluegill and crappie. At present, evidence is lacking that selective killing actually increases desirable fish. In view of the great reproductive potential of gizzard shad any beneficial effects are short-lived.

Application of rotenone has been followed by a sharp increase in fishing success shortly after treatment. This improvement of fishing obviously results from the destruction of the food of predators. At present, it appears that selective killing affects the catch rather than the actual abundance of sport fish. Selective killing may, nevertheless, prove to be valuable in certain situations.

Experimental selective killing in Kentucky led biologists there to conclude that present methods may be practical only on relatively small reservoirs.

COMMERCIAL FISHING

Commercial fishing appears to be the best means by which a higher and more balanced yield of fish can be taken from reservoirs. A continual conflict has existed for many years between sport and commercial fishing interests on southeastern reservoirs. Invariably, sport fishermen succeed in efforts to bar or restrict commercial fishing. Because of this controversy and problems of marketing food fishes, no strong demand has been made for commercial fishing rights in several reservoirs where high-value commercial species are abundant. Carp and suckers can be taken from many waters by gig, bow and arrow, or snagging; however, these methods, although desirable for increased pleasure, do not ordinarily contribute substantially to the total take of fish.

Commercial fisheries, properly regulated, can greatly increase the take of fish from some reservoirs, and the selectivity of the gear for non-sport fish should tend to offset effects of the selectivity of angling for more valuable species.

For effective commercial fishing, there should be an understanding of the economics of the fishery and of the biological features of the fish population. Investigations should determine the capability of a particular reservoir to support a commercial fishery and the best means by which these fish can be removed without unnecessary conflict with sport fishing (Dryer, 1955). Since sport fish constitute only 1.2 percent of the commercial gear catches from Alabama waters of the TVA reservoirs (White, 1956) there is little probability that expanded commercial fishing will result in excessive mortality of sport fish.

INTRODUCTION OF NEW FISH SPECIES

Some reservoirs contain vast numbers of forage fish, principally gizzard shad. This fish has a high reproductive potential and short life span. On some reservoirs it makes up 50 percent of the weight of all fish. Biologists in the Southeast have, therefore, reasoned that the introduction of certain predator sport fish will provide additional fishing by converting shad into sport fish. Some have suggested that species of fish native to impounded streams are best suited for reservoir habitat. This view does not appear entirely sound and should not preclude consideration of the introduction of new fish species.

Most southeastern reservoirs are naturally populated with bluegill, white or black crappie, and largemouth, smallmouth, or spotted bass. White bass and walleye, which usually appear naturally in mainstream reservoirs, must often be introduced into storage, power, or flood-control impoundments.

Sport fish preferred for stocking in the Southeast have been white bass, walleye, and in some waters, rainbow trout. Other species stocked experimentally have been muskellunge and striped bass.

Unless already present, white bass have been stocked in almost every large reservoir in the Southeast. Usually the introduction of 100 adult fish has been sufficient to establish the species. After stocking, white bass ordinarily became common in the reservoir and contribute materially to the sport fishery. White bass provide sport fishing at all times of the year. The fish tend, moreover, to inhabit the headwater areas of major embayments where the success of sport fishing often has been limited.

Walleye frequently have been introduced as adults or fry. Usually these fish contribute substantially to the fishery only in those reservoirs where they occur naturally. Fry are stocked annually to sustain a valuable walleye fishery in Center Hill Reservoir, Tennessee (Fetterolf, 1957), an impoundment in which this fish has not reproduced naturally. Anglers have taken walleye larger than 20 pounds. The stocking of walleye in southeastern reservoirs appears never to have had undesirable results.

Rainbow trout have been planted with varying degrees of success in cold-water reservoirs. These reservoirs usually are small and are cold because inflowing waters are discharged from the depths of storage reservoirs upstream. Introductions of other cold-water fishes have met with little success.

The stocking of seven small muskellunge in Dale Hollow Reservoir in Tennessee indicates the possible value of this fish. Three of the stocked fish are known to have been taken by angling. One tagged fish weighing 2½ pounds at the time of planting weighed 7¼ pounds when it was taken 11 months later.

The striped bass presently supports a sizable fishery in the Santee-Cooper Reservoir in South Carolina (Scruggs and Fuller, 1955). Some of these fish are now taken in the newly impounded Jim Woodruff Reservoir in Georgia, Alabama, and Florida. Both adults and fry have been stocked in several reservoirs in South Carolina, North Carolina, and Arkansas but there is no evidence of success.

In view of the many desirable features of the threadfin shad, it has been placed in several southeastern storage and power reservoirs to correct a lack of small forage fish. Its short life span and small size make it ideal as forage to all sizes of predator fish (Parsons and Kimsey, 1954). The effect of this fish on sport fishing or in suppressing gizzard shad populations has not been reported. However, introduction of the species in waters where gizzard shad do not occur has been followed by promising increases in fishing success. One such reservoir in Virginia is now being studied to determine the influence of threadfin shad upon the fishery.

Threadfin shad have provided vast quantities of food in tailwaters where they were discharged in a dead or dying condition through the turbines.

The judicious stocking of desirable fish in reservoirs of the Southeast thus appears to be useful in fishery management. Introductions of new species and stocking of established ones should be done with caution, however, especially where fish populations may be relatively unstable, or the value of the fish to be introduced has been untested.

MANAGEMENT OF TAILWATERS AND TRIBUTARIES

Management in tailwaters is concerned principally with control of rate of flow, with the better utilization of areas not suitable for trout but too cold for native warm-water fish, and with the improvement of water quality.

Aside from refinements in the determination of stocking needs, trout fisheries in tailwaters can be improved by providing periodic flows below the dams (Parsons, 1957). Water usage for power from storage reservoirs in the Southeast is often limited during the summer. At times no water may be discharged for several days. In tailwaters containing trout, these shut-downs can seriously affect or eliminate the populations. Analyses of the physical characteristics and water usage of the reservoirs can usually provide recommendations for periodic water discharges to avoid such occurrences. Moreover, flushing of the stream washes many terrestrial fish-food items into the tailwater. Periodic water discharges below a dam must be predetermined in order that necessary additional water may be retained in the reservoir for that purpose. Below several dams in the Southeast, the periodic release for trout is one turbine-unit discharge for 1 hour within any 48-hour period (Parsons, 1957). To increase the catch of trout, low-water flows should be provided weekends and holidays when fishing is heavy.

Certain segments of cold tailwater streams not suitable for trout (which may be determined easily by trial-and-error stocking of 4- to 6-inch fish) do not presently support any fishery. Smallmouth bass and other warm-water fish do not reproduce successfully and fish growth is slow in these waters. Most evidence indicates that a majority of the warm-water fish migrate downstream or into warm-water tributaries soon after reservoir operation begins.

Bottom samples in these stream segments indicate that food is abundant enough to support sizable fish populations. Exact determination of the types of food available will be necessary to decide which types of fish are most suited for the waters. Since the warm-water species of sport fish indigenous to the streams of the eastern United States avoid these cold areas, experimental stocking of exotic species may be desirable.

The limited abundance of fish and aquatic organisms in waters below some storage dams indicates the need for improving water quality. Total fishery values of reservoirs and downstream waters would be greatly increased if water for generating power could be drawn from any depth or in many cases, through conduits near the reservoir surface.

No investigations have been conducted to determine the effects of migrant fish (from reservoirs) on non-migratory fish in tributary streams but large-scale invasions surely must be harmful. Small dams on some of these streams have materially reduced upstream migrations (Ruhr, 1957). Installation of others may prove desirable. In Tennessee, the catch of these migrant fish from some streams has been increased by legalizing gigging and bow-and-arrow fishing.

PROMOTION OF ANGLING AND REGULATION OF THE FISHERY

FISHING FACILITIES

Utilization of reservoir and tailwater fishery resources can be increased without long periods of investigation. Public access for boat launching and public lands for shore fishing and picnicking are presently adequate on most reservoirs in the Southeast. On some reservoirs, however, the public must pay for access to public waters.

On reservoirs constructed by TVA and the U. S. Army Corps of Engineers, boat dock and harbor rights are leased to concessionaires. These private agencies may handle boats, motors, and fishing tackle and operate restaurants, cabins, and boat-launching facilities. Alert concessionaires have increased fishing by such additional facilities as: fishing docks, apart from the operator's docks, which are used for a small fee primarily by older fishermen and children; fishing cruisers for party-boat fishing, particularly at night; and heated house docks for winter fishing. These concessionaires have found that provision of fishing facilities for the entire family increases the number of fishermen and the frequency of visits.

Although development of private enterprises is not a biological problem, support by biologists for facilities at boat docks can improve utilization of fisheries.

CONTROL OF PLEASURE-BOATING

Only a few years ago fishing was by far the major recreation on southeastern reservoirs. Since 1950, the increase in numbers of pleasure craft has been tremendous. Few fishermen blame pleasure boating for poor fish catches. Rather, fishermen are opposed to interference by noisy, speeding boats and the frequent dangers of collision or capsizing.

This problem on reservoirs has been discussed by many groups but as yet no action has been taken. One solution may be to zone certain areas for pleasure-craft use. For the protection of fishermen on state-owned reservoirs some states have restricted the size of motors, or have banned pleasure-boating on specific week days. As this problem becomes more acute, fishermen will require state or federal protection in their desire for safe fishing.

ELIMINATION OF RESTRICTED AREAS

Warm-water tailwaters below mainstream dams offer some of the best "reservoir" fishing. It has been estimated that 40 to 50 percent of the fish catch on TVA waters is immediately below the dams (Tarzwell, 1941). "Fish sanctuaries" have been established below several dams in the Southeast. Most or all of these restrictions should be removed in the states where they exist. Other tailwater areas may be closed to fishing in the interest of public safety. However, statistics on drownings show that tailwater fishing is reasonably safe. Unless conditions are unusually dangerous, shore and boat fishing should be allowed in tailwaters except immediately below the penstocks or from dam structures.

LAWS AND REGULATIONS

Most of the southeastern States have liberalized sport fishing on reservoirs. There are no closed seasons on warm-water sport fishes. In some states regulations on reservoir sport fishing could scarcely be improved. Probably the greatest increase in the catch of sport fishermen in mainstream reservoirs would be had by legalizing snagging of all fish in tailwaters immediately below the dams.

Regulations most limiting to reservoir fisheries apply to commercial or food fish. Gigs, bow and arrow, harpoons, snagging, hand fishing, and certain efficient commercial fishing devices are outlawed in many states.

RESEARCH AND INTERAGENCY COOPERATION

RESEARCH

Recognition of fishery problems and possibilities of management in the Southeast has been generally adequate. Lacking, but indispensable, are knowledge of facts and understanding of basic principles necessary to implement management properly. More intensive continuing research by competently trained biologists is necessary to achieve this goal.

One of the greatest needs is evalution of fishery-management practices that are put into effect. Seldom have biologists had the opportunity to study a reservoir over a period of time, initiate management, and evaluate the results. Biologists have necessarily conducted inventories of fishing and fish populations and, until this preliminary work is completed, basic research will be neglected. Furthermore, only a few universities in the Southeast have fishery curricula that can assist state research programs.

Intensive long-term research on at least one of each of the 4 types of reservoirs in the Southeast is needed badly. Better understanding of factors that affect fishing is necessary on one reservoir before findings may be applied to other waters. Among the limnological and fishery problems in reservoirs that need attention are water quality, production of bottom organisms and plankton, population dynamics of fish, predator-food relationships, and effects of water levels on the reproduction and growth of fish.

The difficulty of investigating fish populations of reservoirs has long been recognized. Studies of the many large reservoirs are complicated by artificial, as well as natural, influences. Steep shorelines and deep waters make fish sampling difficult. In addition, too few efforts have been directed toward improving or devising methods and techniques for reservoir study. For example, rotenone long has been used to sample fish but the actual value of the population data collected has never been adequately determined and improved methods for using the toxicant have not been developed.

Extensive experimentation in the use of rotenone should reveal its value and limitations for sampling reservoir fish. Monthly samples taken from the same coves and different coves, both day and night, over a period of at least 1 year, should reveal information that will clarify some sampling problems. A good schedule would require about six 1-acre samples per month. Experiments in sampling deep waters also should be undertaken.

BIOLOGISTS AND TRAINING

Some biologists and administrators in the Southeast believe that an effective fishery-management program on any one large reservoir will require the full-time services of at least one fishery biologist. Notwithstanding the several-fold increase in biologists and students investigating reservoirs since 1949, demands are presently far beyond the researcher's capacities. The shortage of biologists is acute.

Many state biologists with experience on reservoirs are leaving the Southeast as a result of low salaries. So few southeastern universities are training fishery biologists that administrators must recruit elsewhere in an attempt to fill positions. The lack of facilities for graduate training in fisheries in the Southeast is readily understandable. The few universities that indicate an interest in fresh-water fishery courses suffer a shortage of funds. State, federal, and even private agencies then must emphasize to universities the need for fishery curricula. Furthermore, these agencies should aid in their establishment and maintenance.

None of the fishery curricula in universities of the Southeast have emphasized reservoirs in their training or research. Advances in fishery education are possible through grants to universities for training or research on reservoirs. At least, scholarships for graduate students can be granted for the study of special reservoir problems.

The lack of fishery training is only a part of the personnel problem. More incentive must be given to young people of college age to enter the fishery field. Especially needed are better salaries, more reasonable security, and earlier recognition of ability (King, 1956).

COORDINATION OF PROGRAMS

Fishery management on reservoirs may require the efforts of several agencies. Since large reservoirs are constructed solely for other purposes, fishing and recreational developments ordinarily cannot compromise major project uses. At present, fishery management must emphasize measures that can be incorporated into the construction or operation of the project.

Fishery investigations of the Southeast frequently require cooperation of conservation, construction, and water- or power-use agencies (Parsons and Crossman, 1956). Cooperation of these agencies in the past has been excellent. Construction and water-use agencies nevertheless have wisely demanded facts to justify recommended changes in reservoir construction or operations for fisheries.

APPRAISAL OF THE PRESENT STATUS OF FISHERY MANAGEMENT ON RESERVOIRS

The principal fishery problems on reservoirs are: inadequate cropping of fish populations, selective fishing, and deleterious efforts of reservoirs upon downstream and tributary waters.

Principal procedures for fishery management are based on: control of water level and flow, selective timber clearing, introduction of new fish species and other controls of species composition, improving fishing facilities, and education of the public.

Problems of research and management of reservoirs appear to be complex but in many ways they are relatively simple. They appear difficult only because of the lack of research upon which effective management must be based. To give just one example, we are in poor position to make use of the opportunities that exist for controlling water levels for fishery management on most reservoirs because we have not had the research necessary to determine when and how water levels should be manipulated.

Research will not give immediate and unequivocal solutions to all reservoir problems. Many, perhaps most, may be solved only by trial-and-error management, but, properly conducted, this type of program is in itself good research. Education of the public, as slow as it may be, is vitally important if results of investigations are to be applied and reservoir fisheries properly exploited. Fishing regulations as well as tradition still make the fishermen selective for certain fish. Furthermore, large numbers of reservoirs in existence or soon to be constructed and the relatively sparce human populations in the Southeast long will make it difficult to persuade anglers to seek small or less desirable fish. The unfortunate expression "rough fish" has not inspired fishermen to take species so categorized.

In view of the attitude of the fishermen, fishery management of reservoirs must favor the development of high-value sport fishing. Acceptance of this view requires that we meet the strong demands of the fishermen for fishing of the highest quality. At the same time we must continue to increase the use of food and pan fish by sport fishermen and by commercial operations. Ultimately, reservoir fishery management should become merely a process of balancing optimum fish removal with fish production.

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FISH MANAGEMENT PROBLEMS OF LARGE IMPOUNDMENTS ON THE MISSOURI RIVER

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ABSTRACT

Dam construction on the Missouri River is creating a tremendous fishery resource in the million surface-acres of water being impounded in six large reservoirs. Major management problems include obtaining adequate harvest, developing efficient commercial gear and markets for fish products, and the threatening possibility of over-population of the reservoir with undesirable kinds of fishes. Each reservoir is unique in its basic physical and chemical characterstics and must be managed as a separate entity. Water level manipulation holds considerable promise as a tool of fish population management. Improvements in the physical design of tailwaters areas can improve sport fishing. More basic data on the fish habitat provided by these reservoirs is urgently needed if fish management methods are to be developed in time to make full and proper use of the tremendous fishery resource. At present, state fishery research and management programs are not adequate to deal with the problems at hand and little or no outside assistance has been received.

INTRODUCTION

The reservoir system on the Missouri River eventually will consist of six large reservoirs. Fort Peck Reservoir in Montana was constructed in 1937. Progressive completion of the five main-stem dams authorized in the Pick-Sloan Plan has been taking place during the past five years. To date three of these projects (Garrison, Fort Randall and Gavins Point) have been placed in operation and two (Oahe and Big Bend) probably will be operating within the next five years. Total area of the six large reservoirs is in excess of one million surface acres. The individual reservoirs vary in size from 33,000 to 410,000 surface acres, and in depth from 50 to 225 feet (Table 1).

The magnitude of this development and its impact on fisheries resources is tremendous. In South Dakota alone, approximately 375 of the 425 miles of Missouri River will be impounded. The remaining 50 miles will be radically altered by reservoir operation. There will be 2,500 miles of reservoir shoreline and 30 million acre-feet of water impounded — enough water to inundate the entire state to a depth of over 7 inches. The volume of surface water held in the state will be more than doubled.

These impoundments that have been constructed with federal funds have become the responsibility of the states of Montana, North Dakota, South

TABLE 1.—*Physical features of the Missouri River Reservoirs.*
[Fort Peck, Garrison, Fort Randall and Gavins Point are in operation. Oahe is under construction and Big Bend is in the planning stage.]

	Maximum surface area (acres)	Length of reservoir (miles)	Length of shoreline (miles)	Maximum depth (feet)	Maximum capacity (acre-feet)	Normal annual fluctuation (feet)[1]
Fort Peck	245,000	190	1,600	225	19,400,000	10 plus
Garrison	410,000	200	1,600	185	23,000,000	10 plus
Oahe	376,000	250	2,350	200	23,600,000	7
Big Bend	19,800	50	175	50	340,000	2[2]
Fort Randall	118,400	140	575	145	6,300,000	5
Gavins Point	33,000	37	100	55	540,000	4
Totals	1,202,200	867	6,400	—	73,180,000	—

[1] Estimated fluctuation when the entire reservoir system is completed. Prior to that time, fluctuations usually will be greater.
[2] Expected to have "almost constant level."

Dakota and Nebraska with practically no sustaining federal support. And there is not an adequate backlog of fisheries management experience applicable to them. Each state has approached the problems at hand in its own way. Following is the management program in South Dakota.

MANAGEMENT OBJECTIVES

Objectives of the management program must take into account the available funds and manpower and the time schedule for completion of the dams. In South Dakota, funds have been sufficient to employ and equip one full-time reservoir biologist and supply necessary labor on a seasonal basis. In 1954 and 1955, only Fort Randall Reservoir (70,000 surface acres) was in operation. In 1956, Gavins Point Reservoir (33,000 surface acres) was placed in operation and by 1959 Oahe Reservoir (375,000 surface acres) will be operating. Consideration of these factors led to the development of a management program with two primary objectives: (1) obtaining as much information as possible about the developing resources; including physical and chemical characteristics of the reservoirs; species composition of the fish population and reproduction and periods of spawning, age and rate of growth, age at maturity, area and depth distribution of fishes and information on utilization and yield, and rates of fish harvest; and (2) applying promising management techniques as finances and conditions permit. These objectives do not allow inclusion of basic research on such problems as the effect on fisheries of fluctuation of water level, limnological conditions and their effects on food production, effects of pollution and dynamics of developing fish populations. Such knowledge is needed for complete and proper fisheries management of the reservoirs.

However, the limited objectives of South Dakota's management program are being attained. At present, enough knowledge of Fort Randall Reservoir and its fish population has been obtained to serve as a guide for basic management. Similar knowledge is rapidly being acquired for Gavins Point Reservoir. Some of the basic management tenets applicable to Fort Randall Reservoir are: (1) natural reproduction of sport fishes is adequate and there is no need for artificial stocking; (2) physical and chemical characteristics of the reservoir show it to be suited to warm-water fishes only; (3) introduction of exotic fish species is not desirable at present due to the variety and abundance of sport fishes and the possibility of disrupting the present natural population balance; (4) annual harvest from the reservoir is inadequate and probably could be increased at least fifty times without concern of overharvest of any species; (5) at present there is no indication of overharvesting the heavily-fished tailwaters; (6) there is need for a commercial fishery to utilize some of the surplus crop of fish; (7) methods of hook and line fishing must be developed in order to improve sport fishing in the deep and diversified reservoir habitat.

PROBLEMS OF RESERVOIR MANAGEMENT

Problems of reservoir management of the new Missouri River impoundments are many and varied. Each impoundment has its own combination of physical and chemical characteristics and must be managed as a separate and distinct entity. It is impractical, therefore, to concentrate investigations on one impoundment and apply specific findings to the others. It also is impractical to apply directly knowledge acquired in other sections of the country without first testing its applicability to local conditions.

Probably the primary problem of all Missouri River impoundments is, and will be for some years, inadequate harvest and incomplete use of the fisheries resource. This is a universal problem and has been recognized by many persons engaged in fishery management of large impoundments (Irwin, 1956; Miller, 1951; Thompson, 1954). To date, annual harvest from Fort Randall Reservoir[1 2 3] has been less than 1 pound per surface acre. The impoundments are situated in areas of low population density. Access to the reservoirs is poor and facilities for fishermen are poor or non-existent. Without facilities

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[1] Shields, James T. 1955. Report of fisheries investigations during the second year of impoundment of Fort Randall Reservoir, South Dakota, 1954. Dingell-Johnson Project F-1-R-4, 100 pp. mimeo.

[2] Shields, James T. 1956. Report of fisheries investigations during the third year of impoundment of Fort Randall Reservoir, South Dakato, 1955. Dingell-Johnson Project F-1-R-5, 91 pp. mimeo.

[3] Shields, James T. 1957. Report of fisheries investigations during the fourth year of impoundment, Fort Randall Reservoir, South Dakota, 1956. Dingell-Johnson Project F-1-R-6, 60 pp. mimeo.

adequate for continual heavy angler use, fishermen are unable to keep up with changes in habits and locations of the fish. Thus, year-around quality of fishing is reduced.

Another major problem is the lack of development of efficient gear to harvest fish on a commercial basis. The old midwest standbys, trap nets and long seines, are not effective in the impoundments. When the gear problem is solved, there will be the further problem of developing processing plants and consumer outlets for fish products.

Undesirably large populations of certain species of fish, especially rough fish, are likely to become established in certain impoundments. If such occurs, the acreages of water and tremendous numbers of fish involved will pose a major problem of control. Efficient population manipulation seems possible only through development of new management techniques to fit conditions and needs of each reservoir.

Along with these major problems are those which arise from time to time in most bodies of water. The problems of pollution, parasites, diseases and habitat improvement are serious in small lakes, but may be magnified in large impoundments. As the system of Missouri River impoundments develops and ages, new and different problems can be expected which cannot be foreseen at this time.

NATURE OF THE RESERVOIRS

As was mentioned previously, each of the Missouri River impoundments is unique in its physical and chemical characteristics. Thermal and chemical stratification are present in some and not in others. Complete water exchange varies from once every 8 to 10 days during the summer in the smallest reservoir (Gavins Point) to about once a year in the largest (Garrison). The water level fluctuation pattern is different for each reservoir, and maximum probable fluctuation during normal years ranges from 4 feet in Gavins Point to 20 or more feet in others. Primary purposes for construction differ and include flood control, power production and stabilization of downstream flows. Perhaps the only common feature is that the water supply of all is rich in basic nutrients. Chemical analyses of water from Fort Randall and Gavins Point Reservoirs have shown ranges in pH from 7.5 to 8.2, and in total alkalinity from 110 to 175 ppm. Maximum summer temperature of reservoir surface water has not exceeded 82° F., and there seldom have been differences in surface and bottom temperatures of more than 8° F. Some features of Fort Randall Reservoir of fisheries interest are shown in Table 2. But even the water supply of downstream reservoirs will be affected by storage and release patterns of upstream reservoirs. The larger reservoirs probably will develop thermal and chemical stratification, thus creating changes in thermal and chemical conditions of release waters. Productive capacity will be different for each reservoir and will change from year to year in the same reservoir, depending upon water supply and operations for multiple-use purposes.

At present the fish populations are in a development stage that reflects the radical change from river habitat to reservoir habitat. In Fort Randall Reservoir reproduction and survival of most species of fish present was exceptionally good during initial flooding of land in 1953. A list of these species includes shortnose gar, goldeye, gizzard shad, bigmouth buffalo, smallmouth buffalo, river carpsucker, carp, channel catfish, black bullhead, largemouth

TABLE 2.—*Some features of fisheries interest of Fort Randall Reservoir, South Dakato.*[1]

	1954	1955	1956
Water chemistry—summer mean:			
Total alkalinity in p.p.m. (surface–bottom)	126–142	—	161–159
pH (surface–bottom)	8.0–7.9	8.1–7.9	8.1–7.9
Turbidity in p.p.m. (surface)	Less than 25	Less than 25	Less than 25
Dissolved oxygen in p.p.m. (surface–bottom)	7.0–2.3	7.4–4.9	8.0–5.7
Water temperature (degrees F.) summer:			
Maximum (surface)	82	82	77
Mean (surface)	79	76	75
Mean difference between surface and bottom	8	4	5
Composition of net catches (percent by number)—summer:			
Frame nets:			
Rough fish[2]	65	24	6
Pan fish[3]	34	75	93
Game fish[4]	1	1	1
Gill nets:			
Rough fish[2]	82	66	52
Pan fish[3]	17	25	29
Game fish[4]	1	9	19
Annual sport fishing utilization and yield:			
Number of fisherman-days	35,000	41,000	47,500
Number of fish taken	114,900	105,200	89,400
Number of fish taken per surface acre	2.30	1.50	1.28
Pounds of fish taken	31,400	36,000	39,900
Pounds of fish taken per surface acre	0.63	0.51	0.57

[1] See text footnotes 1, 2, 3.

[2] Principal species: Shovelnose sturgeon *(Scaphirhyncus platorynchus)*, shortnose gar *(Lepisosteus platostomus)*, goldeye *(Amphiodon alosoides)*, gizzard shad *(Dorosoma cepedianum)* bigmouth buffalo *(Megastomatobus cyprinella)*, smallmouth buffalo *(Ictiobus bubalus)* river carpsucker *(Carpiodes carpio)*, carp *(Cyprinus carpio)* and freshwater drum *(Aplodinotus grunniens)*.

[3] Principal species: Black bullhead *(Ameiurus melas)*, bluegill *(Lepomis macrochirus)*, white crappie *(Pomoxis annularis)*, black crappie *(Pomoxis nigromaculatus)* and yellow perch *(Perca flavescens)*.

[4] Principal species: Channel catfish *(Ictalurus lacustris)*, largemouth black bass *(Micropterus salmoides)* and sauger *(Stizostedion canadense)*.

black bass, bluegill, white crappie, black crappie, yellow perch and sauger. The large 1953 age classes of most of these species dominated the population in 1954, 1955, 1956 and in some cases in 1957. Since 1953, reproduction and survival of most rough fish (Table 2) has been poor while that of pan and game fish (Table 2) has been good in one or more of the years. Thus as the size of the 1953 age class is diminishing, the fish population structure is changing according to reproduction and survival conditions created by the reservoir. To date, reservoir conditions have been favorable for establishment of a fish population composed chiefly of desirable fishes. Alterations in operation of Fort Randall Reservoir as the entire system of reservoirs develops or the changes in biological conditions caused by age alone may cause radical changes in the fish population. Continual study will be required to determine changes in population development, their causes and possible methods of improving conditions suitable to the maintenance of a desirable fishery.

TOOLS OF MANAGEMENT

In these reservoirs there is one important tool of management not applicable to most natural water areas. It is planned manipulation of water levels. Potentially, this is a powerful tool. Basic patterns of water fluctuation are determined by needs for flood control, power production, irrigation and navigation. However, in the integrated system of Missouri River reservoirs there are possibilities for varying these patterns to aid fish management. An example of this is control of carp reproduction by planned water drawdowns at Fort Randall Reservoir in 1955, 1956 and 1957 (see pages 23 to 33 of this Volume of the Transactions). Other possibilities include improvement of spawning conditions for desirable species and increasing food production through inundation of naturally or artificially vegetated areas. It is essential that more information on effects of water level changes be acquired so that specific patterns of fluctuation can be designed which will benefit the fisheries resource. The drawdowns for carp control at Fort Randall Reservoir involving over 100,000 acre-feet of water a year were carried out with little or no adverse effects on other water uses and demonstrate that through close cooperation with reservoir operating agencies it is entirely possible to make extensive use of water level manipulation for management of fish populations in large impoundments.

Another promising tool of management is improved design of tailwater areas below the dams to allow maximum harvest of the fish that concentrate there. It is known that backwater areas adjacent to the swift tailwaters attract and hold species such as bass, crappies, bluegills and bullheads, which ordinarily do not concentrate in swift water. In northern latitudes, such backwaters will freeze over in the winter and furnish winter fishing through the ice in addition to fishing in the swift open water. Improvement of some physical features of a reservoir to aid fish management is often possible after a dam is constructed; but the golden opportunity lies in determining desirable and undesirable fish management features associated with existing dams and then incorporating the desirable features in the construction plans of new projects.

Warm artesian wells, when available, also can be used to concentrate fish. In several Missouri River impoundments there are warm (about 80° F.) artesian wells around which fish concentrate, especially during fall, winter and spring. In reservoir planning the flow of such wells could be directed into selected areas (probably small bays) where fish could concentrate and be more available to anglers.

Sport fishing regulations are nearly adequate at present and do not pose major problems in management of large impoundments on the Missouri River. Regulations in South Dakota allow year-around fishing for all species. There are no size limits (except a 6-inch minimum on trout), and the liberal creel limits are seldom filled. Commercial fishing is being encouraged. Minor legislative changes are needed to allow commercial fishing by equipment such as gill nets, and to permit sport fishing in reservoirs with the use of lights and other fish-attracting devices. The situation as pertains to laws is similar in several neighboring states having reservoirs. Already some minor changes have been effected in these states to allow greater harvest from the reservoirs. It is believed that other desirable changes in regulations can be had if a factual basis to warrant them is found.

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Part 4

Other Symposium Contributions

[Including papers presented at Trout Farming, Federal Aid
and Watershed Management Symposia]

SOME STATE PROBLEMS ASSOCIATED WITH THE COMMERCIAL TROUT INDUSTRY

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Abstract

The growing commercial trout industry is making a valuable contribution to fishing and fish management in Western United States. In addition to trout reared for sale as food and to provide pay-fishing, the industry is a source of trout eggs and fish not infrequently purchased to supplement production of state hatcheries. Trout are also sold for stocking of approved private and public waters. It is necessary that commercial hatcheries be licensed and state control exercised over distribution of fish from them. This prevents indiscriminate and unplanned planting of public waters and introduction, accidental or otherwise, of undesirable species of fish. Such control also aids in curtailing the spread of fish diseases. Proper regulation and inspection of commercial hatcheries can both benefit the industry and protect state waters.

Introduction

U. S. Fish and Wildlife Service records indicate that there are presently some 590 state and federal fish hatcheries and about 1,100 private hatcheries in the United States. There is need and room for hatcheries of both kinds but the rapid growth of the commercial trout industry does pose some problems for state fisheries administrators. Private hatcheries, of course, are more numerous in some states than in others and problems differ. For example, in 1952, there were 41 such businesses in Idaho but only one in Wyoming.

In Western United States, the area with which the writer has personal acquaintance with the trout industry, commercial trout producers raise trout for the restaurant trade, for pay-fishing, and for the stocking of private and public waters. They also produce eggs and fry for sale to other private hatcheries or to governmental agencies. Some hatcheries specialize in one aspect of the business, some in others, and some try to cover the entire field. Development of "U-Catch-Em" pay fishing at commercial hatcheries provides a place for anglers to fish both during the general trout fishing season and when it is closed, thus adding to general recreational opportunities even in areas of good trout streams.

Over the years many fine relationships have been developed in the West between commercial hatchery operators and personnel of state fish management agencies. However, there are some aspects of the operations of some commercial hatcheries that are a cause of concern among state administrators. This concern is growing as the industry grows. For the most part it stems from lack of knowledge or disregard on the part of the commercial operators of the responsibilities assigned state fisheries agencies by law.

RESPONSIBILITIES OF STATE AGENCIES

A state fisheries agency is by law delegated the responsibility for fish management in all public waters of the state. This includes planned management programs and policies, including stocking; prevention of introduction of undesirable species of fish, or elimination of them if present; and prevention of spread of fish diseases. While most administrators agree that planting of private waters with fish from commercial sources is beneficial because it somewhat relieves fishing pressure on public waters, they are opposed to unauthorized planting of commercially-reared fish in public waters. Such stocking interferes with management plans and may be unnecessary or even harmful.

To maintain control over management of public waters most states require that commercial hatcheries be licensed and have laws prohibiting stocking of privately reared fish in public waters unless the stocking has been approved by the state fisheries agency. In Wyoming, sometimes such regulation is resented by commercial hatchery operators, especially by those operators who reside in other states and wish to sell their fish for planting in the state. Such resentment is understandable. But on the other hand, if an orderly and effective fish management and stocking program is to be maintained, records have to be kept of all stocking and the fish planted must be known to be free from disease. It might be noted that this problem has been recognized at the national level. Under Public Law 258, transportation of fish across a state line is illegal if the operation is in violation of laws of either the exporting or importing state.

PROBLEMS ARISING FROM UNCONTROLLED DISTRIBUTION OF FISH

Uncontrolled distribution of fish results in problems of two kinds; those associated with spread of fish disease and those resulting from introduction of undesirable species of fish.

Hatcheries, where fish are usually crowded, are fertile ground for development of fish diseases and from hatcheries these diseases can be easily spread. This problem has been recognized by the American Fisheries Society which has recommended at various times through its resolutions that the states adopt laws regulating importation of live fish and eggs and requiring inspection for disease and parasites, and even quarantine if necessary.[1] A generally accepted and satisfactory system of state inspection has not yet been developed. For the present the best approach seems to be to have the importer secure a certificate of inspection from the state where the fish are secured. Such inspection will probably necessitate a nominal charge. In the long run, it will be to the advantage of commercial operators to cooperate because it is well known that many serious hatchery diseases such as furunculosis, ulcer disease and virus infections can be transported, both by trout and trout eggs. Sometimes even though a disease is present in a hatchery, a more virulent strain may be imported. Import regulations should require disinfection of all fish eggs and shipping containers. In the case of foreign imports, inspection could be required at the port of entry.

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[1] See especially Vol. 84 (1954), pp. 376-377 and Vol. 85 (1955), pp. 308-312.

The problems arising from the indiscriminate stocking of spiny-rayed fishes and rough fish are well known. Much effort is now being made to eradicate these fishes in waters that they have taken over. Since commercial hatcheries sometimes also rear and sell warm-water fishes, control of the distribution of such fishes is especially vital. A number of commercial hatcheries now raise bait fishes. This provides state administrators an excellent opportunity to promote production of kinds of bait fish that are least harmful if they escape or are released into public waters. There is always the danger that shipments of bait fish, especially if imported, will contain spiny-rayed or rough fish that will rapidly repopulate a rehabilitated water if released, accidentally or otherwise, into it. Some idea of the possibilities for such introduction and dispersal of unwanted warm-water fishes can be had from estimates of present production of bait fishes from Minnesota alone—about 100 million minnows and suckers a year, having a value of 2 million dollars. On the basis of use of minnows by licensed Minnesota anglers (about 5 dozen a year) the sale of bait fishes in the United States may be close to a billion fish a year.[2]

Cooperation Between Commercial Operators and State Agencies

It is apparent from the lists of commercial hatchery operators which are published occasionally that many hopeful hatcherymen start out in the business but only a few are eventually really successful. It is the established operator who has experience and who uses the practical innovations as they are developed who succeeds. Although problems at state and commercial hatcheries differ somewhat, the commercial operator can often learn a great deal from state fish culturists — and *vice versa.* To get such cooperation it is necessary that the commercial operator conform to state regulations and realize that they exist for good reasons. On the other hand, state agencies are glad to recommend reliable commercial suppliers of fish to prospective buyers and will welcome the help the commercial operator can give in stocking private waters that the state hatcheries cannot take care of — providing, of course, the commercial operator cooperates by conforming with state regulations. The better we are able to make fishing, the greater the demand for fish will be and both state fisheries programs and commercial operators can expect to benefit.

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[2] Minnesota estimates by John Dobie, Minnesota Department of Conservation.

PROBLEMS IN COMMERCIAL TROUT PRODUCTION

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ABSTRACT

The commercial trout-rearing industry in the United States is a big and growing industry that has many problems different from those of governmental trout hatcheries. Fish of specific saleable sizes often must be available throughout the year. Such a supply is obtained by utilizing uneven growth of trout, using different egg supplies, crowding and release and adjusting feeding. Pellet feeding has proven useful in the industry. Trout raised commercial usually sell for between $0.85 and $1.25 a pound and this price includes cost of labor, food and maintenance, and necessary profit. Present problems of the industry include depression of the market dumping of trout by marginal producers and competition from imported trout, difficulties in financing trout farms, shortage of hatchery operators and suitable labor, and lack of research on problems of commercial trout production.

INTRODUCTION

Commercial rearing of trout is big business in the United States and promises continued growth. This industry produces dressed trout as a table delicacy and trout for stocking of natural and artificial fishing water. In recent years, there has also been a considerable trend toward pay-fishing by the public at trout farms.

Scattergood (1957) in his Report on Commercial Fisheries to the American Fisheries Society estimated that there are between 500 and 600 privately-owned trout farms in the United States and that their 1955 output was about 4 million pounds of trout, of which about half was sold dressed. Dewitt (1954), who sent questionnaires asking for information about trout farms to private trout hatchery operators in California, Oregon, Washington, Nevada, Colorado, Utah, Wyoming, Montana and Idaho, reports that the 185 operators who returned questionnaires had about six million dollars invested in the business.[2]

The purpose of the present paper is to discuss some problems of the commercial trout industry and of the operators of commercial hatcheries—especially in the light of the author's own commercial operations at Troutdale Ranch, Gravois Mills, Missouri.

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[1] President of the U. S. Trout Farmers' Association.

[2] According to recent information from the U. S. Fish and Wildlife Service (letter from William Hogen, Jr.). There are currently in the United States 354 private fish hatcheries producing trout and pond fishes and 770 private establishments producing bait fishes there are 91 Federal and 492 State fish hatcheries.—Ed.

THE SIZE PROBLEM

Commercial trout growers have a problem not often encountered in governmental hatcheries. It is the necessity for having trout of saleable size on hand at all times during the year. A restaurant owner, who purchases 10-ounce trout, will expect to be able to buy such trout at any time. In contrast, the goal of governmental hatcheries is usually trout of a specified size for stocking only in spring or summer.

Large commercial hatcheries can solve the size problem by quick-freezing and packaging trout when they are of proper size. But most trout farms producing fish for the table sell them fresh-dressed and a constant supply of saleable-size fish must be had by hatchery management. This production problem is further complicated by changing customer preferences as to size of fish. Seven years ago trout weighing three to the pound were preferred with only a few buyers of half-pound fish. Today 12- to 14-ounce fish are most in demand.

There are several ways to obtain a constant supply of trout of saleable size. If a hatchery operator depends entirely on his own brood stock for eggs, he can expect that spawning will be completed within a 60-day period, and starting dates for rearing his stock will be limited. The fastest growing trout of any hatch may reach marketable size in one year, but these fast growing individuals usually make up only two or three percent of the total hatch. Growth of the rest must be controlled —slowed or accelerated— so that the fish reach saleable size in groups properly spaced over the following 12 months. Making use of uneven growth of fish by grading is useful but this does not solve the size problem completely. Growth may be increased by releases of trout from heavily populated raceways into areas with ample water and then feeding them heavily. Conversely, growth may be retarded by planned crowding.

Frequently qualified fish culturists express the opinion that operators of commercial hatcheries overcrowd their fish. They do. And do it both to retard growth and because necessity for profit. To stay in business, often requires use of every gallon of available water, sometimes even beyond its optimum fish-supporting capacity.

Commercial hatcheries that do not have their own brood stock and buy eggs can control maturities of their fish more easily. Trout eggs are usually available from commercial sources from November through May. With proper spacing of egg purchases and judicious feeding a year-round supply of trout of all sizes, including saleable fish, can be maintained without too much difficulty.

OPERATIONS AND FINANCES

The selling price of a pound of trout raised commercially is usually between $0.85 and $1.25 a pound. This price includes many items not ordinarily given much consideration in governmental hatcheries. Overhead chargeable to initial investment, property and equipment maintenance, as well as labor and food costs and necessary profiit all appear in the selling price of the trout. The complete commercial hatchery or trout farm requires much equipment for successful operation, some of which is not ordinarily associated with fish raising. A typical inventory for a usual trout farm would include buildings, raceways, ponds, live-hauling truck, tractor, pick-up truck, refrigeration compressors, band saws, bench saws, drill press, ice crusher, road grader, feed trailer, lawn mower, egg hatching troughs, spraying equipment, tanks, metal screens, seines, typewriter, and cash register. All require preventive maintenance and occasional replacement.

Many commercial hatcheries are located in isolated areas where expensive maintenance of grounds is not necessary. This cuts down the overhead. But during recent years the trend has been toward opening part of the hatchery facilities for public fishing on a pay-as-you-catch basis. Ground maintenance then becomes necessary for the fishing area must be kept clean and attractive. In connection with public fishing, it is often necessary to advertise by putting a series of highway signs. Their cost and maintenance must also be added to the price of the fish.

In recent years feeding costs have been reduced because of development of commercial pelleted trout foods. These are now widely used in the commercial trout business. Prior to their development more labor was needed because of the necessity for preparation of food for each day's feeding. Now pelleted food is purchased in sacks, poured into buckets and fed to the fish. In my own operations, using pelleted food, the yearly costs of food and labor are about equal.

As a result of the development in food technology, much of the older equipment in many hatcheries is now obsolete, there no longer being need for refrigerators, and grinders for meat products, food mixers and much other standard hatchery equipment of a decade ago. On the other hand, new equipment is being brought out some of which has proven quite valuable in commercial trout rearing. In the latter category are automatic feeders, egg and fry cabinets, fish-loading conveyor, revolving screens and automatic fish graders. With present high labor costs it is essential that the operator keep well-informed on such developments.

There are many uncertainties in the trout business, both biological and economic, and because of these it is usually difficult to obtain adequate initial financing through normal channels. Usually initial financing has been had through personal credit and character of the operator. Well-established hatcheries are in a better position because they have a record of earnings and a list of steady customers. But even for those in most cases capital expenditures for expansion and new equipment must come from earnings of the business.

COMPETITION IN THE INDUSTRY

In the trout industry, as in all other businesses, there is competition. This competition is, of three kinds; domestic, foreign and governmental.

When markets are slow, some domestic producers under stress of heavy inventories may dump large quantities of trout on the open market at low prices. This depresses the market for trout and injures growers who are operating in an orderly manner and trying to maintain fair prices and profits. Usually such competition comes from marginal producers who are operators of small hatcheries and who have no great investment at stake, no particular market or sales outlet and less-than-satisfactory management. Dumping by such marginal producers has a disurbing effect on established markets of individual commercial growers and on the welfare of the trout industry as a whole.

Foreign competition in the form of imported frozen trout, has increased greatly since World War II. Most of the imported trout have come from Denmark and Japan. At a time when American trout farmers were selling their product at 75 to 90 cents a pound, Danish and Japanese trout were laid down at New York and San Francisco, packaged and frozen for 42 cents a pound. This was less than the American production cost. One reason for the seriousness of the competition was that American dollars bought more abroad than they did at home. Even after Danish trout had passed through importer, distributor, and wholesaler, each of whom took a profit, the selling price was still 15 to 20 cents a pound less than that for American trout.

Another difficulty arising from foreign competition has been that the imported trout were frequently listed on restaurant menus under such names as "Rocky Mountain Trout," "Eastern Brook Trout" and "Ozark Mountain Trout;" names that had for many years been identified with the American product. And since some of these trout were of inferior quality the American customer attributed this to a deterioration of domestic trout. To correct this problem, the National Board of U.S. Trout Farms sponsored in Congress a bill entitled "The Trout Labeling Bill". This requires that all imported trout be labelled in such a manner that the customer would know the country of their origin. This bill was passed by both the House and Senate during the last session but was killed by presidential veto.

Governmental competition exists mainly in the form of free trout stocking of private waters. If such fish were stocked only in public waters, these waters, and the general fishing public would benefit; and the commercial trout industry would also benefit from the sale of trout for stocking private waters. There is need for clarification of federal trout stocking policies and better understanding of them both by the public and commercial growers.

RESEARCH FOR COMMERCIAL TROUT PRODUCTION

Little research has been done on ways to improve commercial trout raising. This is largely because individual hatcheries are scattered nationwide and, until recently, were associated only in local or regional organizations that were not able to finance research. It is recognized that much valuable trout research has been done by federal and state agencies, but too often commercial trout producers are not familiar with it. Then too, there are many of the problems in commercial trout farming that are peculiar to the industry.

As a research development of great value, commercial pelleted trout food has already been cited. Pelleted diets are now widely used in state and federal hatcheries. The Michigan diet might be cited (Grassl, 1957). However, they have often been found inadequate unless periodically supplemented with meat. For example, Phillips (1956) states, "The main restriction in the use of pellets is that they cannot be fed for long periods without feeding meat at least once a week, and perferably twice, if serious mortalities are to be avoided." Diets have now developed beyond this stage and there are several commercial pelletized foods that have been used successfully by commercial growers without meat supplementation during the past two years. The value of past research in disease control should also be mentioned.

It is essential that the commercial producer interest himself in trout research. One of the aims of the U. S. Trout Farmers Association is promotion of better understanding between governmental fishery agencies and the private trout industry and cooperation in research on mutual problems.

LABOR AND MANAGEMENT PROBLEMS

The trout business, generally has lower wage scales than most industries; wage scales generally similar to agriculture. Since wage rates reflect profits and profits in the trout industry are usually not high, hiring and keeping efficient labor is often a difficult problem. The labor problem is most acute for hatcheries near urban centers but even in rural areas commercial trout hatcheries cannot compete with most industries and with government, especially in fringe benefits. Too often the labor available to the trout industry is that which is not wanted elsewhere and, even on an equal pay basis, most workers prefer inside employment with regular hours to the necessary irregular schedule and sometimes uncomfortable working conditions at a hatchery. Considerable labor turnover appears unavoidable until the price for trout, which has remained nearly stable for five years, increases and allows payment of better wages.

There is a shortage of competent commercial trout farm managers. Medium-sized and large hatcheries need managers who are versed in trout production, sales management, labor relations, and cost accounting and who have had experience in commercial production. Training both in biology and business methods is essential. There are excellent opportunities for men who can qualify. It should be emphasized that commercial trout operations hinge on profit; the business must pay or it doesn't stay in operation.

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SOME PROBLEMS OF PRIVATE TROUT HATCHERY OPERATORS

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Abstract

Disease, nutritional, and environmental problems in commercial production of trout are discussed, including mortality and age of spawners, copepod and gyrodactylid infections, suitable water temperatures, diseases (especially red mouth and back peel) and inspection of fish. It is concluded that experiences with hatchery procedures have varied greatly and often the commercial trout producer must adjust methods to fit his particular needs and conditions.

The disease, nutritional, and environmental problems at private trout hatcheries are not fundamentally different from those of the federal and state hatcheries even though most trout and salmon raised in governmental hatcheries are liberated at definite times, while the private trout farmer crops his stock continually. However, disease and unnecessary mortality are often prevalent in private hatcheries because many private operators in the West seem to believe that, for sake of economy, they must crowd trout excessively and raise them on as cheap a diet as possible. The statement by Dr. Fish (1938) is particularly apropos: "Perhaps for our general peace of mind it is just as well that we do not know all that we might about the cost of dead hatchery fish, but from the little we do know, it appears that every time the hatcheryman hands a one-dollar bill to the food man out the front door, the Grim Reaper makes out the back door with fish worth a dollar and a half." In trout rearing there are accepted practices, but there are few hard and fast rules and procedures to which exceptions cannot be found. An attempt is made here to point out such diversity. Often our thesis might well be "the opposite can also be true."

For example, at one of our hatcheries it was a regular occurrence to lose about 20 percent of the brood stock after spawning. Was this loss too high? A survey of a number of private and state hatcheries indicated that some lost very few of their brood fish after spawning, while others lost up to 20-30 percent and some nearly 100 percent. Mortalities associated with these losses were generally fungused, but fungus is probably not the true cause of death. One private trout farmer said that generally the fish died from fungus, but one year the fish died at about the same rate and no fungus was present.

Copepods, *(Salmincola)*, on rainbow brood fish, although not a serious trout parasite in the East according to Dr. Snieszko (private communication), have often been a serious problem in the West. At present no satisfactory solution to the copepod problem is known. At some stations fish are spawned for three years and then disposed of because of copepods. At other stations no brood fish are kept — the brood fish being held in other waters.

In the past it has often been thought that fish should be starved a month or longer before spawning. But nowadays, brood fish are usually fed right up to the time of spawning, or to a couple of days before spawning, and then put back on food soon after. There is divergence of opinion concerning taking of eggs from 2-year-old brood fish. A California state hatchery takes eggs only from 2-year-old rainbow trout and then plants the adults in public water, because it seems not economically feasible to hold the adult fish longer. However, in a Washington hatchery eggs are not taken from two-year-olds because sport fishermen do not want fish reared from 2-year-old brood fish. Similarly, one private trout farmer throws away eggs from 2-year-old brood fish, claiming that the eggs are small and poor and resulting fish weak.

It has been usually considered that the optimum temperature for holding brood rainbow trout, taking eggs, and incubation and rearing is around 50° F. or slightly higher. However, according to U. S. Trout News (Eastman, 1957) one private concern has been successful in holding its brood fish at 58° F. and incubating eggs and rearing fry and fingerlings at this temperature. Success is attributed to good food for the brood fish. There is also a state station that raises rainbow trout in water from a spring at 60° F. But here it has not been possible to spawn brood fish successfully and incubate eggs through their development stages. The brood fish are taken to another station with colder water where they are spawned and eyed eggs returned to the warmer water for fingerling rearing. Dr. Donaldson at the School of Fisheries, University of Washington, Seattle, informs me that he has spawned and raised rainbow trout at temperatures above 60° F. The eggs were taken at 62° F. and incubated in the mid-60's through hatching, which took 11 days. The young fish were feeding at the end of 19 days. In this case, success at the warmer temperatures is attributed to selective breeding.

Mortality of eggs has been attributed to poor nutrition of the adult. According to Seguin (1957): "Feeding liver only once a month (or even once a week) and pellets all the other days resulted in high mortality of eggs during incubation and among the newly hatched larvae. But feeding pellets one day and liver or spleen the next gave very good results." Egg mortality has also been attributed to diseases of the adult fish, physical shock, improper spawning techniques and to light.

Fry loss may be high among progeny of certain females and may be associated with effect of environmental conditions on the eggs as well as fry. It may be caused by leeches. "White spot" may be associated with fry losses, but we do not know the mortality cause. Myxobacteria may sometimes be responsible for severe fry losses.

Fingerling losses have been attributed to many causes. Losses from external parasites can usually be quite satisfactorily controlled. For this many fish farms in the Snake River drainage used potassium permanganate. We used permanganate in 1940 in a frantic effort to control bacterial gill disease among salmon and found that its efficacy varied depending upon the organic load in the water and that it was not too effective for controlling the bacteria. We used it three days in a row and found that the greatest objection to its use was that the fish would go off feed. However, a number of trout raisers report that fish treated with permanganate do not go off feed and can be fed immediately after treatment. It appears therefore that potassium permanganate can be successfully used to control parasites if its characteristics at a particular hatchery are known. In California potassium permanganate is not used extensively but acetic acid is generally used for flush treatments for the parasitic infections and copper sulphate for the bacterial infections on the gills and on the surface of fish. Copper sulfate as a flush treatment for bacterial gill disease is often used daily for two or three days or on alternate days for a series of two or three treatments.

In treating a disease in a population of fish, the ideal treatment would be one whereby the chemical is sprinkled over the surface of a pond after the water is turned off and, after the necessary period of time for treatment, the chemical flushed from the pond. The closest approach to such an ideal treatment is the flush treatments used under circumstances of crowded conditions and warm water. Here prolonged treatment can not be used and the dip treatment is too severe for the fish and is too time consuming. A concentrated chemical solution added at the head of a pond or trough is allowed to flow through, treating the fish. The results are usually quite satisfactory.

Red throat disease is quite common in the Snake River drainage. Fish with this disease become sluggish and dark in color; a reddish inflammation develops in the mouth and at the base of the fins and at the distal portion of the intestine. The intestinal contents become a yellow liquid and the spleen may become almost black. Wagner and Perkins (1952) studied this disease in California and found it present on numerous occasions in commercial trout hatcheries.

The Germans for a long time have combated a disease called "dropsy" which is caused by a bacterium similar to that which causes red throat. It has been shown to be present in carp and also rainbow trout. Immunization was an early method of combating the disease; young fish were deliberately infected, making the survivors resistant. Development of resistant stocks has also been suggested. Chloromycetin is now used, each fish being given an injection (see Schaeperclaus, 1957). It is common practice among the private trout growers to administer one treatment of a sulfonamide to clear up red throat, however in a federal hatchery in Idaho and hatcheries in California, a sulfonamide is used from seven to ten days to clear up an infection. Nigrelli (1957), in a recent paper on the same or very similar disease mentions that if the organism was injected into healthy fish a general infection developed within one hour and the fish soon died. When cultured material was rubbed on the skin of the fish it caused death within twenty-four to forty-eight hours and when the organism was fed, fish died in ten to twenty days. When the fish culturists handle fish, they find that red mouth may appear in the next day or two, indicating that the injuries inflicted by handling probably break the mucous layer and allow the bacteria to enter and kill the fish. This is somewhat similar to what Nigrelli found. Also, Wagner and Perkins (1952) mentioned that *Gyrodactylus* infections were always present whenever they had red mouth disease, indicating that the trematode created a site of infection for the bacteria. From the literature it is apparent that feeding of diseased material can produce red mouth in ten to twenty days, yet many fish farmers use viscera from the market fish as trout food. This is an unsafe practice even though it is claimed that the older fish that are fed these entrails are resistant to the disease. What is needed is a complete, cheap pelleted food that would make feeding of entrails unnecessary.

Pellets for rearing fish are used exclusively and successfully in many places, but have been unsuccessful elsewhere. But it should be pointed out that nutritional requirements of different strains of rainbow trout vary as well as environmental conditions in hatcheries. Phillips (1957) mentions the relationship of vitamin deficiencies and temperature and says, "It is often impossible to rear trout during the summer on diets that were satisfactory during the winter." Concerning pellets as a complete food, Phillips further states, "Recently pelleted fish foods have come into wide use in trout hatcheries, but—as far as is now known—supplemental fresh meat must be fed regularly." The nutritional requirements of fish are being determined. When they are all known, scientifically compounded pellets no doubt will be prepared. Before that time arrives, empirically compounded pellets will be used. Many commercially prepared pellets, as well as those prepared by federal and state agencies, are being and will be tested for nutritional adequacy and cheapness. One objection that has been raised to the use of pellets is that they are more expensive than the old types of feeds. However, Grassl (1957) states: "The adoption of dry pelleted diet as standard rations by all state fish hatcheries in Michigan increased trout production in pounds by 60 percent and reduced fish food expenditures by 40 percent." In using these pellets in Michigan beef liver was used, a minimum of at least one day every three weeks, indicating that the pellet diet was not nutritionally complete.

A condition in fish referred to as "sunburn" or "back-peel" should also be mentioned. A lesion develops in the area between the head and dorsal fin. A grey spot first appears, this is followed by a necrotic area of the skin which sloughs exposing the muscle. This lesion was found to be correlated with excess use of phenothiazine by Harold Wolf, of the California Department of Fish and Game (private communication). He recommended use of phenothiazine for control of the intestinal flagellate *Octomitus (Hexamita)* but warned that it should not be used more than three times because of "back peel." I have seen this type of lesion develop from the excessive use of phenothiazine out-of-doors while the lesion did not develop on shaded fish in a hatchery. This lesion has been produced in fish fed pellets while similar fish at the same hatchery under the same conditions fed the regular production diet did not develop the lesion. The exact opposite has also been observed: fish at a hatchery developed the typical "back-peel" lesion when fed the production diet, while similar fish under the same conditions fed pellets did not develop the lesion. Three different research groups are now working on this disease or condition.

The Fish Importation and Inspection Laws and Regulations which California put into effect a short time ago have raised considerable comment, but they seem to be of value especially for protection from red throat disease which is not present in California State hatcheries. Only healthy fish may be brought into the state, only healthy fish transported within the state. Hatcheries are inspected and if fish are not healthy they cannot be moved. Inspection is not only beneficial to those receiving fish, but it can protect those who ship fish by pointing out existence of disease that should be treated.

California biologists examining fish for the presence of disease wish to effect a minimum delay for a load of fish entering the state. Therefore, their examination at the border checking stations is streamlined and not as detailed as might be required for an examination complete enough to determine presence of all diseases. From a practical point of view complete examination at a port of entry is hardly possible since it would require the following: (1) gross examination for disease symptoms, (2) examination of body scraping under a microscope to determine presence of external parasites; (3) examination of gills grossly and with the microscope; (4) examination of blood smears and smears from the organs, fresh and stained for abnormal conditions and for parasites and bacteria; and (5) examination of gastro-intestinal contents. In addition, different types of bacteriological media should be inoculated with material from the viscera and incubated at two temperatures. If bacterial growth develops it should be identified. Livers. kidneys, and spleens should be blended and inoculated into healthy fish of the same species. Some of this blended material should be passed through bacteria-proof filters before being inoculated into fish to show the possible presence of viruses or virus-like agents. Material should also be preserved and prepared for examination by a histopathologist, for such examination sometimes reveals diseased conditions unrecognized by any other procedure. An examination such as outlined, if carried on by a trained crew, would take three to four weeks or longer, but would be necessary for certain detection of diseases of unknown etiology.

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SUGGESTIONS FOR REDUCTION OF NATURAL MORTALITY IN FISH POPULATIONS

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Abstract

Illness, in fish as well as in other animals, when caused by an infectious disease, is often not the result of infection with pathogens alone. In many cases the pathogens and hosts can exist side by side without development of disease symptoms. Such symptoms, with resulting illness or death, appear only when the balance of mutual tolerance between the host and the pathogen is shifted in favor of the pathogen. Factors of several different kinds may render a host susceptible to disease; such things as poor nutrition, unfavorable physical conditions in the environment and the hereditary make-up of the fish itself. Drugs may allow temporary control of infectious diseases but for the long-range control it is better to increase the resistance of the host.

Some suggestions are given, based largely on experience with disease control in hatcheries and fish farms, for minimizing natural mortality of fish from infectious diseases.

Nature of Fish Disease and Natural Mortality

When considering factors affecting *natural mortality* of fishes with the view of possibilities for control of such mortality, it is first necessary to define this term. In nature living creatures do not exist in isolation but are exposed to numerous external physical, chemical, and biological factors, as well as to the effects of their own physiological and aging processes. From a fish's point of view the specific cause of its mortality makes little difference, but it has been the custom of fishery workers to include under the term "natural mortality" all mortalities that cannot be attributed to deliberate activities of man; such activities as netting and sport fishing. All of the factors causing natural mortality cannot be considered here and this discussion will be limited to those cases which are called "fish diseases" and when they are caused by bacteria and viruses. Our discussion must be further limited by practicability of disease control. Such control is practical in the limited waters of fish hatcheries but in natural bodies of water the amount of control feasible is limited by size of the body of water and economic and recreational value.

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The premise that all that is needed to cause an infectious or parasitic disease is a simultaneous presence and contact between pathogens or parasites and susceptible hosts has long been accepted by the general public and is still held by many biologists. Lately, epidemiologists are finding that for outbreak of epidemics among humans, animals, plants, and even microorganisms more is needed than the presence of pathogens. It is becoming clear that disease or mortalities from infections and infestations often occur only under specific favorable ecological conditions. This present concept of the natural history of infectious diseases, as pointed out by Burnet (1953), is much more complicated than the classical pathogen-host concept of Pasteur and Koch.

Recent aspects of disease and epidemiology have been recently brought into focus by Dubos (1954, 1955). In his 1955 article he states:

> The germ theory of disease has a quality of obviousness and lucidity which makes it equally satisfying to a schoolboy and to a trained physician. A virulent microbe reaches a susceptible host, multiples in its tissues and thereby causes symptoms, lesions and at times death. What concept could be more reasonable and easier to grasp? In reality, however, this view of the relation between patient and microbe is so oversimplified that it rarely fits the facts of disease. Indeed, it corresponds almost to a cult-generated by a few miracles, undisturbed by inconsistencies and not too exacting about evidence.
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> There are many situations in which the microbe is a constant and ubiquitous component of the environment but causes disease only when some weakening of the patient by another factor allows infection to proceed unrestrained, at least for a while[2]. Theories of disease must account for the surprising fact that, in any community, a large percentage of healthy and normal individuals continually harbor potentially pathogenic microbes without suffering any symptoms or lesions. This type of dormant infection seems to occur widely, not only among men and animals, but, also probably among plants and even microscopic cells.
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> Thus the simple fact that a population survives and flourishes in a given environment implies that its members are endowed with a high degree of natural resistance to the microbes normally present in that environment. This natural resistance stems in part from evolutionary selection of the strains best endowed with mechanisms for withstanding infections, and probably in part from the development of adaptive reactions in response to early exposure to the microbes. Suffice it to say that their over-all effect is the establishment of a state of biological equilibrium between man or animals on the one hand, and the microbes endemic in the community on the other.

An example of the effect of ecological conditions is the influence of temperature on furunculosis, ulcer disease, columnaris disease, and the septicaemia caused by *Aeromonas liquefaciens.* At the Rome, New York hatchery Dr. Wolf (private communication) was not able to induce either ulcer disease or furunculosis in brook trout kept at temperatures lower than 45°F. However, both diseases were active in the same batch of trout and at the same time at temperatures above 50°F. Columnaris disease (except the psychrophilis form) is known to attack both cold- and warm-water fishes at temperatures above that which is optimum for particular species of fish (in Symposium, 1954). *Aeromonas liquefaciens* causes the most severe septicaemias in warm-water fishes (carp dropsy is the best known type) in spring when the temperature of water increases and fish are coming out of their winter semi-dormancy. This bacterium is common in fresh water but only under conditions not yet clearly understood does it cause heavy losses among fishes (in Symposium, 1954).

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[2] In fishes: Columnaris disease, infections caused by pseudomonads and gill disease, are examples of this relationship.

In general, however, our knowledge is slight concerning the influence of chemical, physical and even psychical factors on outbreaks and severity of fish diseases. This should be a fertile field for future investigational work.

In addition to influence of environmental factors on fish diseases, inheritable characteristics of the parasites and hosts and their interplay have great influence on the manifestation of diseases and the magnitude of mortalities. Gowen (1952) summarized this situation as follows:

> Through efforts of workers in the field it is now recognized that agents of diseases and their hosts each are organized and get their characteristics from the development of an inheritance, made up of distinct genes. By specifying the gene for a particular disease reaction it has been possible to show that genes act as protectors from a given disease, as independent of the disease reaction, and as causative agents in the disease syndrome. A clinically manifest disease only results when the proper combination of the genotype of the victim, the genotype of the pathogen, where one is necessary, are properly sychronized with the environment.

In 1925 Embody and Hayford increased resistance to furunculosis by breeding the most resistant brook trout surviving this disease. Similar results were obtained by Davis (1953). Wolf (in Symposium, 1954) reported investigation of resistance to furunculosis and ulcer disease in a number of strains of brook trout and found that some of them showed a significant natural resistance to these diseases. Wolf's observations have been confirmed af the Leetown station where in a susceptible population of brook trout ulcer disease appeared and caused heavy mortalities but no symptoms of ulcer disease appeared among the resistant strains of brook trout held under identical conditions. As previously reported (Snieszko, 1957) even when some strains of brook trout under test were constantly exposed for several months to experimental infection with ulcer disease, furunculosis, or both, losses were much smaller among the resistant fish.

To the casual observer it might seem that the number of diseases, fish diseases included, is continually growing. This increase is more apparent than real because with progress in fish pathology, diseases are being described which were previously unknown or little known. Also because of changing environmental conditions, transfer of fishes, and intentional or unintentional development of domesticated strains of fishes, diseases which have long existed in the wild in latent and unnoticed form sometimes have become epizootic. Feeding of unsterilized fish products to young fishes, which are usually more susceptible to disease than adults may also be conducive to explosive epizootics (Snieszko, 1953; Watson, Guenther and Rucker, 1954).

The idea that maintenance of sanitary conditions, prophylaxis and therapy may result in absolute control of fish diseases should be placed in proper perspective. Such measures permit only reduction of losses from infectious diseases but can not be expected to eliminate them. Only knowledge of the entire complex of factors which influence the outbreaks of epizootics among fishes can furnish means for effective long-range control.

A program designed to gain such knowledge should include research on genetic resistance of hosts and inheritable virulence of pathogens and a study of the relationships between them.

It is very likely that in this respect the interplay of the hereditary characteristics between fishes and their pathogens operates in a similar matter as with some of the mammals (Gowen, 1952). One has to keep in mind, however, that the influence of genetic factors may be modified to some extent by ecological and nutritional factors, and in a large measure by variation in the chemical composition of water, availability of dissolved oxygen, presence and concentration of pollutants, density of fish population and presence of carriers, vectors, or intermediate hosts.

Immediate control measures, however, cannot be slighted. Sanitation and prophylaxis including study of the action of drugs on the pathogens and of the side effects of the drugs on the hosts all merit more consideration. It has recently become evident that some drugs, though miraculously effective in control of some pathogens, may upset ecological and physiological conditions within the host, so as to render it susceptible to fatal infections, so called superinfections, with some fungi as for example *Candida albicans.*

Since the introduction of sulfonamides for treatment of fish diseases such as furunculosis in 1946 by Gutsell (in Symposium, 1954) drugs have been frequently used as the *only* means of disease control. This has resulted in some cases in the appearance of drug-resistant strains which have defied further treatment with these drugs (Snieszko and Bullock, 1957). Frequently, however, sulfomemides have been used without real need or incorrectly (improper dosage, wrong sulfonamide or incorrect duration of treatment) and resulting complications were simply invited. Drugs have an important role in fish disease control, but they should be used judiciously and only when really needed. Their long-range effectiveness should not be overestimated. For the effective and practical control of fish mortality from infectious diseases with use of drugs, influence of environmental and genetic factors upon the disease must be understood.

Suggestions for Reduction of Natural Mortality

The following suggestions based mostly on the experience with control of diseases in hatcheries or ponds are made for minimization of natural mortality from fish diseases:

1. Proper diagnosis of the disease in question is essential if disease control is to be attempted[3].

2. Whenever possible the natural balance between the pathogen and host should be undisturbed by human interference. Such a balance usually has been established by natural selection in waters not stocked with hatchery fish and losses from infectious diseases are apt to be small, even if some fish have a latent, symptomless infection. In fish farms, farm ponds and hatcheries, such a pathogen-host balance seldom exists because of management practices. In any case all stocked fish should be free from a communicable disease.

3. When a disease problem exists, an artificial balance can be established by selection and breeding of the disease resistant fishes. This is essentially a speeding up of the process outlined above; natural selection is replaced by artificial selection.

4. Sanitation should also be applied when practical. The aim of it is prevention of introduction of agents causing disease. This can be done in hatcheries by disinfection of the water supply and of all the utensils and by keeping away wild aquatic and terrestrial animals, as birds for example, which may act as vectors of the pathogens. In natural waters this is difficult, but at least the hatchery operator should make sure the equipment used for transportation of fish is well disinfected between uses.

5. Prophylaxis, such as periodic treatment of fish with drugs or disinfectants, is economically justified only when it is known that a specific disease occurs with some regularity at the location, or if part of the establishment is already infected. Only those external disinfectants or internal drugs should be used whose effectiveness has been well established and they should be used only as recommended. Changes in drug use should be made only in well designed and properly conducted experiments where results of new approaches can be evaluated. It is both uncertain and dangerout to use methods of prophylaxis or treatment without first testing them on experimental basis. Unfortunately costs usually prohibits use of drugs or chemicals to lessen mortalities in waters other than those in hatcheries or ponds.

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[3] Diagnosis of fish diseases and their proper treatment is greatly hampered by lack of fisheries workers trained in fish pathology. There is at present also shortage—almost lack—of facilities for such training. Only New York University gives courses leading to degree in fish pathology. While several other universities, especially Washington, Michigan and Cornell, present courses or course material on fish diseases and parasites, there are at such schools no full time fish pathologists. There is the training school of the U.S. Fish and Wlidlife Service at the Trout Nutrition Laboratory at Cortland, New York and research facilities are located at the Federal laboratories at Leetown, West Virginia and Seattle, Washington. In addition there are several state fish disease laboratories, one at the New York Aquarium, but none of these have more than one full-time pathologist. As well as the general training needed for practicing fisheries biologists, both teachers and research specialists in fish diseases are needed. It is suggested the necessary background training could be had from courses in veterinary medicine

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PLACE OF GAME AND FISH IN MULTIPLE USE OF WATERSHEDS

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ABSTRACT

Fish and wildlife in the near future will often have to be fitted into multiple use programs for watersheds. This involves compromise between various desired uses of land and water; uses which may be compatible, conflicting or independent. If fish and wildlife are to receive proper consideration in a multiple use program, it is essential that there be more factual information on relationships of wildlife to habitat and on wildlife values. Public support must be won through the use of these facts.

Rather than describe a watershed program, let it suffice to say that the watershed approach to area use and planning is the most logical. As our economy which has long been based on surpluses of land and water, shifts to one in which resources are in shorter supply, it will be necessary to plan resource use more carefully. Since the watershed is the basic physiographic unit — encompassing both soil and water, the watershed program is certain to expand.

There are many watershed programs underway at present. The programs of Michigan encompass conservation practices for all the renewable resources of the watershed but are directed specifically at improvement of trout fishing. Wisconsin has many organized community watershed projects. New York State, some of the New England states and North Carolina are all active in watershed planning and rehabilitation. There are also federal watershed programs.

It must be recognized that in planning for the use of any resource that is in short supply, there will be conflicts between the various groups using the resource. In watershed planning such conflict may be intense and even bitter. We must secure for fisheries and wildlife resources the recognition their values warrant and obtaining recognition is our problem as professional conservationists.

Problems presented in the development and management of private and public watersheds differ, so these two types of watersheds will be discussed separately. On private watersheds, fisheries and wildlife values will generally be enhanced by the instituting conservation practices designed to shift land uses from a pattern of exploitation to one of truly sustained yield. Farmers and other occupants of a watershed can be eduated to accepting a watershed program on the basis of the benefits of tabilized stream flows, conserving of soil, increased crop production, in- reased values of forest, woodlot and range, and as protection to their ax base. Increased fish and game populations will generally follow, but ith private landowners the role of fisheries and wildlife is usually one secondary consideration and a by-product of wise management of the nd for other uses. The only alternative is to offer the landowner sufficient ncentive for production of wildlife crops to give them primary consider- tions. Only with such incentives can additional consideration be won for sheries and wildlife resources on areas made up largely of private holdings.

On public watersheds there is our greatest management opportunity and lso our greatest possibility for conflict between groups representing various nterests. It is here we must win a place for wildlife resources if they are o be enjoyed by generations yet to come. How can these conflicts be esolved and the objective of a pattern of multiple land use which includes place for fish and game be reached. First we must be able to set values n fisheries and wildlife. In defending and establishing the value of these esources, we must be prepared to express and to calculate their value in everal ways. Part of our population can argue and evaluate only on the asis of the dollar and there are times and places where a dollar value must e assigned to game and fish. In assigning such values, the most common nethod has been to calculate the cost of reducing to possession. However, ve should recognize that if we can use only this argument, we are handi- apping ourselves. Hunting and fishing is also a recreational experience, and how can such an experience be assigned a monetary value, and we hould ask ourselves, should we even attempt to assign a monetary value o experience.

For example, a married man works to maintain a home. Once a home s established, most men continue to support it, so they must feel that they re adequately compensated for the cost and effort. Yet I am sure most f us would be extremely hard put to break down the compensation we eceive into individual items and assign a dollar and cents value to each. When you kissed your wife goodbye to come here, how much did it cost ou and was it worth it? How much is a walk in your garden worth to you, ow much is an hour in front of the fireplace on a cold winter night? By he same token, how much was your last fishing or hunting trip worth?

Other comparisons may be used to explain the value of hunting and ishing. It is oftentimes profitable to express values in terms of the number f people who hunt and fish. Such an approach should be appreciated by oliticians. The emotional approach can also be used to good advantage. The point is that we must learn to use all honest arguments in order to vin the widespread recognition needed to protect the values of our wildlife nd fisheries resources from the competition of other interests.

Let us not be deceived. If certain large segments of our population have their say, very little attention will be given to fisheries and wildlife interests in planning for the future use of our public watersheds. As an example of the type of thinking against which we will have to defend our fisheries and wildlife resources, I wish to describe some excerpts from a recently published Colorado newspaper. These particular articles deal specifically with plans for the future use of water. They clearly indicate that fisheries and wildlife interests will be ignored by many. First, may I explain that there is an organization known as the Arkansas Valley Watershed Conservation Association. This is part of the Colorado State Watershed Conservation Association. This organization has announced that they represent all water users and that they are working together to assure the most equitable allocation of water. However, only industry, agriculture and municipal water uses are represented. Game and fish representatives have been politely told that since they have no legal standing under law, (as beneficial users of water) that they cannot expect to have a voice. This unfortunately, is true, only irrigation, industry, and domestic use, are recognized as beneficial uses of water under Colorado law. This allows the leaders of such groups to say conveniently that game and fish can be produced only on such areas and with such water as may be left over after all "beneficial users" get theirs. This particular article went on to quote arguments from an industrial leader that the greatest future of Colorado lies in industry and that industry should be assigned higher water use priorities than they have at present. There was a rebuttal by agriculture but no consideration was given or even mention made of recreational and wildlife values.

In planning for inclusion of fisheries and wildlife resources on our public watersheds, let us first explore what will be asked of us and what we will need to know to successfully present our case. First, it is certain that watershed planning will involve the principal of multiple use. And it is essential that the meaning of multiple use is clearly understood, especially in relation to benefits to fisheries and wildlife resources. Multiple use can be defined as the management concept of use of an area — in this instance a watershed — by several users simultaneously and regulating each use so as to yield the maximum total production. To the harrassed fisheries or wildlife administrator who first encounters the term "multiple use" it may seem to be more valuable than it really is. He is so accustomed to being ignored that even to be included on the team comes as a most pleasant surprise.

Multiple use is not a panacea by which everyone can get everything he wants from a limited area without regard for other interests. Seldom will individual uses be able to attain the maximum production under a program of multiple use and herein lies trouble. It is only natural that managers and representatives will desire to produce the most for their group. For each group to be restricted to something less than the maximum yield will be irksome and mediation and intelligent decisions must be made by a governing authority. We as representatives of fisheries and wildlife interests must take steps to assure our resources adequate recognition in decisions determining future multiple use of public watersheds.

The term "watershed rehabilitation" should also be clearly understood. It is safe to say that whatever represents good practices for conserving soil and water is also apt to improve game and fish resources of a watershed. However, watershed rehabilitation should not be confused with watershed management. Let us not slip into the erroneous assumption that what is best management for one use is automatically best management for other resources. This is particularly true of fish and game resources. For example, practices for maximum timber production are not those best for game management; such practices as elimination of weed species such as aspen and complete reforestration with elimination of forest openings are obviously detrimental and contrary to good game management. Under the principal of multiple use, the forester would not be permitted to produce timber without regard to wildlife. Likewise, the livestock producer, if given a free hand, would probably eliminate shrubs and browse in favor of increased production of grasses for his grazing animals, and this program would also be detrimental to game production. Under multiple use, he would have to modify his approach. Individuals desiring only maximum production of water from a watershed for downstream use suggest that erosion can be prevented by grasses as well as by trees and shrubs and that riparian trees and shrubs, with their high transpiration loss, should be eliminated. Such a program would be detrimental to both the game and fish populations on a watershed. Under the principal of multiple use, compromise between uses would be necessary.

In integrating watershed uses under the multiple-use concept, three terms describing the relationships of one use to another must be understood. The first of these is "compatible." Uses are compatible if increased output of one increases the output of the other. The second is "conflicting". Uses are conflicting if increased output of one decreases the output of the other. The third is "independent". Uses are independent of one another if the increased output of one has no effect on the output of the other. All three types of relationships exist between use for fisheries and wildlife and other uses. About the compatible and/or independent uses of a watershed we need have little concern, but in many areas there is conflicting use between wildlife and other interests. Here is where we must fight to protect our interests. Where such conflict occurs, priorities of use must be assigned. These assignments in many instances will be made by federal or state land managers. In many cases such managers will consider all aspects of conservation, but they will also be foresters and others concerned primarily with their own particular resource. They are seldom qualified to manage fisheries and wildlife resources.

Most land managers will honestly want to give recognition to all uses according to their public value, but there are several factors that hinder the obtaining of proper recognition of our game and fish resources. Some of these are as follows: (1) The concept that fisheries and wildlife values must always be by-products or secondary to other uses. (2) The concept that good management of other land resources automatically provides the best management of fisheries and wildlife resources and (3) the difficulty of properly comparing fisheries and wildlife resources in terms of dollars and cents with monetary returns from other users. In addition, special interest groups will endeavor at every opportunity to gain considerations above and beyond what their interests warrant.

A great amount of detailed, specific, factual information on the management and yields of the fisheries and wildlife habitat is needed. In supplying this type of information, the fisheries and wildlife profession can make its greatest contribution. If our watersheds are to be managed under the multiple use concept, then advocates of each use must be able to evaluate the effects of other uses on the production or use of their particular resource. I am quite certain we, as professional fisheries workers, and the same holds for professional wildlifers, are unable to evaluate with any great exactitude the effects of other watershed uses on our resources. We can say siltation is bad, removal of shade bad or good, water level fluctuation is bad, and make other general statements, but this is not sufficient. We are going to be asked how much silt is how bad, and how much can be tolerated without serious loss to the resource. We are going to be asked the degree to which any amount of water fluctuation will be destructive to our fisheries resource. The resources we are trying to protect are not now receiving adequate consideration, partly because such specific answers are lacking. There are few research programs directed at learning these answers. We as a profession must see to it that the effects of other types of watershed use on our resources are better understood.

Now let us attempt to look forward to when public watersheds will be managed under the principles of multiple use but with provision for granting priority to one use or another on lands where interests are in conflict. It seems rather likely that certain pressures and philosophies will always attempt to relegate fisheries and wildlife resources to a minor status. Under such arrangement, we would be assigned first consideration on no land or water area where conflict with other interests exists. This would place us in one of two positions. We would be assigned first consideration only in areas unfit for any other use and these will eventually include only bare rock hillsides for game and dry stream beds for fish, or we will be forced into a low priority position on the more favorable and useful areas. We must be able to point out to the public that on some areas the uses of hunting and fishing will yield the greatest return. I cite, for example, big game winter range. Big game biologists are in agreement that the lack of winter range is the factor limiting our big game herds in the west. They say that less than ten percent of the public domain in Colorado can be classified as winter deer range. If this is true, should not the game resource be awarded top priority on these key winter range areas. Similar situations exist where relatively small areas and small volumes of water are of critical importance to large fish populations. It is of tantamount importance that we establish the concept that certain portions of our country will yield a greater return to the public as game and/or fish production areas than from any other use.

Let us now look forward even further to a time when population pressures have forced us to the ultimate in good management of all our watershed resources and maximum total yield on each watershed has been achieved. This will come if present human population trends continue. There is a limit to the outdoor recreation that good management can provide, but there are many who still think that space to live in, work in, and play in is unlimited. Such people, a few generations ago, said that our timber, bison and salmon were inexhaustible. Today such people treat our game and fish resources and the areas needed to produce these resources as if they too were inexhaustible or unnecessary. Everywhere "developers" or "exploiters", depending on the point of view, beat the drums and promote the finest trout fishing, the finest elk shooting and unspoiled lakes and streams. They urge more cottages, more and better roads, more drainage, more filling of marshes, and in considering fish and wildlife resources as static and indestructible they will destroy that which they seek.

It is up to our profession in cooperation with the wildlife profession to secure the facts necessary to establish the true value of our fishery and wildlife resources. We must use these facts to win support of the public in backing intelligent and equitable management of our public lands. We must enlighten those who would destroy our fish and game resources through ignorance and we must defeat those who — through greed and selfishness — would ignore and destroy the public's fish and game resources and the space these resources require.

In this discussion of the importance of wildlife resources in the watershed approach, I have endeavored to incorporate the ideas and concepts of a rather large number of authors and individuals. I sincerely thank them for their interest and the assistance they have so freely given.

MANAGEMENT OF FOREST WATERSHEDS AND IMPROVEMENT OF FISH HABITAT

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ABSTRACT

Management of forest watersheds in the western United States for protection against floods and sediment and to improve water yields can also be very beneficial in fishery management. Some of the important hydrologic processes that operate on watersheds are discussed. The principal kinds of watershed protection and water yield improvement problems are outlined and discussed in relation to maintenance of desirable fish habitat. Need for research to determine quantitative hydrologic relationships on watersheds and develop methods of forest management for better regulated and higher quality streamflow is emphasized.

INTRODUCTION

The volume and stability of water flow and the amount of soil eroded on forest watersheds have long been known to have important bearing on the value of streams and lakes for fish management. Basically, watersheds yield water to streams as runoff over the surface of the soil or as seepage flow down through the soil mantle. If rain falls or snow melts more rapidly than the soil can absorb it, excess water runs off over the surface. Unchecked surface runoff erodes and carries large amounts of soil from watershed slopes. It also produces quick and erratic streamflow surges that scour stream beds and tear banks. Such surges, laden with sediment are harmful to fish. They may kill fish directly. They destroy fish foods and impair or even obliterate spawning beds. On the other hand, water that seeps through the soil mantle to streams usually has none of these harmful effects.

The principal benefit, therefore, of good forest watershed management to fish and fishing, is one of encouraging absorption of precipitation by soils so that surface runoff is prevented and water is stored in the soil mantle for better regulated and more continuous release to streams. Regulated and sustained streamflow of this sort is also beneficial for most other water uses.

BASIC HYDROLOGIC PROCESSES

Several fundamental hydrologic processes affect the amount of precipitation that ultimately finds its way to streams as seepage flow. Brief review of the more important processes may be useful as a basis for understanding the watershed management problems to be discussed.

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Interception.—The first and one of the most obvious effects of plant cover on a watershed is interception of precipitation by foliage. On forested watersheds 10 to 50 percent of the annual precipitation may be intercepted and never reach the ground. The amount of such *interception loss* depends upon comparative amounts of rain and snow, the total amount of storm precipitation, and the kind and density of plant cover. It is greatest in dense coniferous forests such as those in snow pack regions that are the headwaters of many western streams.

Depletion storage.—Initially, as water from rain or snowmelt enters the soil, it forms a thin film around each soil particle. The amount of such water ordinarily ranges from 0.4 to 1.0 inch per foot of soil mantle depth. It is held so tightly by forces of surface tension that it cannot be removed or depleted by gravity or the transpirational pull of plants.

Retention storage.—As more water enters the soil, it fills the smaller spaces between particles. When full, these spaces can hold from 2.0 to 3.0 inches of water per foot of soil depth. This water is retained by surface tension against the force of gravity. It can be removed by plant roots but cannot move through the soil or contribute seepage flow to streams until all of the smaller soil pores are filled.

Detention storage.—After retention storage capacity has been satisfied, the larger pores in the soil can hold from 0.1 to 3.0 inches more water. This water is not held against gravitational force but is detained temporarily as it moves through the soil to streams and underground aquifers. Detention storage prolongs the time of water percolation in the soil mantle, thus sustaining streamflow. It is also a safety valve because it is an emergency storage capacity during prolonged rainy periods when no more retention storage capacity exists.

Seepage flow of water in detention storage is the normal process by which most water (up to 95 percent of the streamflow) is contributed to streams in well-vegetated forest watersheds. Evidence of this is the presence of soil mantles on even steep slopes. For many years most of the precipitation falling on these soils must have been disposed of down through the mantle rather than over the surface; otherwise they would have been eroded away.

The normal hydrologic processes of forests can be changed and have been changed by human activities, especially those that disturb the vegetative cover. Vegetation is highly responsive to the management activities of man; it can be altered profoundly by timber cutting, grazing, road construction, recreation, and fire. The hydrologic processes influenced by vegetation, therefore, often can also be substantially altered. The qualitative characteristics of hydrologic processes, or those that indicate what kind of response can be expected in the processes to a change in forest management, are generally known. For example, we know that soil compaction by tractors usually reduces infiltration capacity; this increases surface runoff and erosion, and decreases the amount of water reaching streams as seepage flow from detention storage. Not nearly as well known are the quantitative characteristics of these processes, or those that define the magnitude of such responses. There is great and immediate need for better understanding and definition of these quantitative relationships. Some progress has been made, but more is urgently needed.[2]

WATERSHED PROTECTION PROBLEMS

Two major kinds of watershed protection problems are encountered on forest lands: (1) maintaining effective surface runoff and erosion control of watersheds subjected to continued use for timber production, grazing, and recreation, and (2) restoring such control on watersheds where it has been lost through over use, abuse, or some catastrophe, such as wildfire. The problems of maintaining watersheds in satisfactory condition present some of the most difficult management situations. In the long run problems of watershed maintenance are the most important ones, otherwise they may degenerate into even more serious restoration problems. Currently, however, the problems of restoring damaged watersheds are most pressing because of such spectacular consequences of mismanagement as floods and mud-rock flows.

Forest management for watershed protection has two specific objectives: (1) holding down of high water flows, and (2) control of water quality. Both require stable soil mantles and stream channels, conditions beneficial to fish as well as to most other water uses. Six important hydrologic conditions are needed to hold down high streamflow peaks:

1. High soil infiltration capacities
2. High soil permeability
3. High water storage capacity in the soil mantle
4. Stream channels free from sediment and other debris
5. Slow snowmelt rates
6. Facilities for surface storage of water.

Control of water quality, especially the sediment loads of streams, requires four hydrologic conditions in addition to those needed for controlling streamflow peaks:

1. Protective vegetative cover on the soil surface
2. Anchoring of soil by binding with roots and other organic material
3. Low surface runoff
4. Well-sodded or rocky channel banks to prevent scour.

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[2] For more detailed discussions of these hydrologic processes the reader is referred to E. A. Colman's textbook, VEGETATION AND WATERSHED MANAGEMENT, and to PLANT-SOIL-WATER RELATIONSHIPS by Lassen, Lull, and Frank.

Wet-mantle floods.—In humid forest areas, heavy precipitation as rain or snow is frequent and, even on well-forested watersheds, more water may enter the soil than it can hold. Retention and detention storage are both filled. Large amounts of water then bleed out of the soil and become surface runoff that can generate floods and erode soil. This kind of occasional flooding is normal and inevitable regardless of how carefully the forest is managed. Not normal, however, is the increased severity and frequency of such floods and the sediment they carry where logging and road construction practices have damaged the storage capacity of the soil and failed to control surface runoff.

Water storage in forest soils can be greatly influenced by the amount of timber removed from a watershed. Where timber is clear cut in blocks, interception of precipitation and shading effects of the forest canopy are negligible for several years while a new forest stand is getting established. During this period more rain and snow reach the ground. Transpiration losses decrease suddenly after timber removal, and this reduces the retention storage opportunity of the soil mantle. Having more water to handle and less effective storage capacity, the soil mantle begins to yield seepage flow sooner and faster. It also becomes saturated more quickly and then yields surface runoff concurrently with seepage flow. This combination of conditions aggravates normal wet-mantle floods substantially.

This chain of hydrologic events poses an important question, especially concerning the management of timber in snow-pack forests. How can the timber be cut so that the rising stage of streamflow begins earlier and the recession stage continues longer, thereby lengthening the period of high-stage streamflow without increasing the peak flow above normal streamflow peaks? This is a major forest watershed problem that requires intensive research. The influences of different kinds of timber stands on interception and evaporation processes that affect snow accumulation, and on the various heat exchange processes that determine snowmelt rates need to be determined and evaluated. Satisfactory solution of this problem should benefit fish by minimizing damage to their food supplies and spawning beds.

Dry-mantle floods.—Summer "cloudburst" type rains capable of producing violent "flash" floods occur frequently over most of the West. Floods from such rains are normal wherever extensive areas of slabrock characterize the surface of a watershed. Where a plant and soil mantle has developed, almost all torrential rainfall is infiltrated into the soil mantle and such floods almost never occur. However, if the plant cover is damaged excessively, leaving much of the soil bare, rates of water infiltration into the soil can be reduced so drastically that most of the rain never enters the ground but becomes surface runoff. This condition can produce spectacular floods having discharge rates far in excess of those from even the largest snowmelt floods. Although "flash" floods of this kind can occur and have occurred on damaged forest watersheds, they are more characteristic of overgrazed or burned range watersheds.

Effects of such floods on fish are devastating, especially in smaller nursery streams, where even one flood can completely tear out the entire drainage bottom. The importance of developing forest and range management practices that maintain or restore control of high-intensity rainfall where it first strikes the ground cannot be over-emphasized.

WATER YIELD IMPROVEMENT PROBLEMS

Another approach to watershed management that may possibly have considerable beneficial effects on fish and their habitat, especially in small nursery streams, is deliberate management of forests to increase the amount and improve the timeliness of streamflow. Demands for such management are increasing to meet expanding water needs of industry and agriculture. Some large streams offer dam sites for regulating streamflow by surface storage, but many smaller tributaries have steep profiles that provide few sites for dams to store early season runoff. Consequently, most of the early season flow is lost downstream, leaving water needs in upper valleys dependent upon direct diversion of low summer and fall streamflow. This low flow period in the fall is a critical time for fish. Their habitat is normally restricted because of low water, and it becomes even more restricted when diversions are made for industrial and agricultural uses. Increased summer and fall streamflow is needed, therefore, not only for these latter uses, but also to improve fish habitat by minimizing its restriction.

Several hydrologic conditions are required to increase the amount of streamflow and delay the time at which it occurs. Increase of annual streamflow requires:

1. Reduced interception losses
2. Reduced evaporation from snow and water
3. Reduced transpiration losses.

Changes of streamflow timing requires:

1. Reduced snowmelt in winter and prolonged melt in spring
2. Deep permeable valley fills
3. Increase in surface storage, if possible.

The best opportunities for manipulating hydrologic processes to improve water yields are in forested watersheds at high elevations where most of the annual precipitation is snow. Here, water stored in the snow pack during the winter is released gradually throughout the spring and early summer months. Only recently have lumber demands and wood utilization methods improved sufficiently to stimulate accelerated timber harvest activities in these forests. If increased water yields from them are to be useful, then peak flows and sediment must be held in check. Methods of managing these forests need to be developed so that any increases in streamflow are delivered as seepage from detention storage and not as surface runoff. These increases in streamflow need to be distributed more uniformly over the recession stages, thereby prolonging streamflow later into the year without increasing either the height of its peak or the amount of early season runoff. Should this objective prove attainable, it will provide better sustained streamflow during at least part of the low flow period so critical to fish.

Limited research indicates that timber cutting in these forests can increase water yields. However, the magnitude of increase in relation to the forest management treatments required to produce them, and the extent to which timing can be altered are far from being known. It is important to have quantitative information on these relations. Solutions to these and other problems concerned with water yield improvement, such as the effects of riparian cover removal and induced drifting of snow on high elevation ranges, require more intensive research efforts.

Watershed management of the type discussed in this paper will not prevent all floods, nor will it stop all erosion, but it can provide the control of water and sediment that is needed on most of our forest lands. It also shows great promise for the regulated production of high-quality water needed for industry and agriculture, and for the maintenance of productive fisheries.

THE STATES AND FEDERAL AID IN FISHERIES

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Abstract

The Federal Aid in Fisheries Act has proven to be of great value to the Southeastern States. Since 1951, 123 Dingell-Johnson projects have been initiated in these states and the following suggestions are made for the future facilitation of the program. Some Southeastern states are continuing to issue county fishing licenses and/or free fishing licenses. It is suggested that these states would be better able to participate more fully in the Federal Aid program if they would require all resident fishermen to have a state-wide license. No priority of project selection on a regional or national scale is desirable. The individual states are best qualified to determine which phases of fisheries work should be emphasized. Continued success of the Federal Aid program is dependent upon the states' willingness to hire and keep competent professional personnel.

There is unanimous agreement in the southeastern United States that the Dingell-Johnson Act has been of tremendous value to the establishment of sound state fisheries programs. Prior to the passage of the Federal Aid in Fisheries Act in 1950, there was barely a handful of qualified professional fisheries workers in the Southeast. Since that time every state has acquired at least a nucleus of professional biologists and some states now have fairly adequate research and management staffs.

It is agreed that the act itself is basically sound; however, some states have been having difficulty in receiving maximum benefits under the act because of out-moded and unrealistic state laws. Some southeastern states continue to sell county fishing licenses as well as state-wide licenses. The cost of the county license is in every case lower than that of the state-wide license, although it is known that local fishermen fishing under a county license almost always harvest more fish than do non-residents of the county fishing under a more costly state-wide license. Therefore, the county license is actually discriminatory in that it allows a greater harvest at a smaller fee by a limited group of people of a resource that is by law and tradition the property of all the people of the State.

The county license system probably does not affect the amount of federal aid monies available to the respective state, as those fishermen who buy county licenses very rarely buy state wide licenses. The total number of licenses sold, therefore, is probably what it would be if there were only a single state-wide license. However, the county license system does have a bearing on the amount of money available to the state for matching federal funds on approvable projects because the state is receiving less money into its treasury than it would if it had only the one state-wide resident license.

It is believed that should those southeastern states, which now issue county fishing licenses, repeal that license in favor of a mandatory state-wide resident fishing license, they would find themselves much better able to take full advantage of all allocated federal funds.

In some states in the Southeast and possibly in states in other regions of the country there are laws allowing certain groups of people, such as veterans, persons under 16 and over 65, cane pole and/or bait fishermen, to fish without a fishing license. These laws are economically unsound, are very probably unsound psychologically and politically, although there are those who will disagree, and directly affect the amount of apportionment of federal funds for fisheries work.

Since 1951, when federal monies were made available to the states, 797 projects of all types have been approved and implemented. One hundred and eighty-four of these have been completed to date and 590 are current. In the southeastern states a total of 123 projects have been initiated. Thirty have been completed, 91 are continuing and two have been cancelled.

Federal Aid projects have been and are so diverse in scope that a thorough discussion here of individual project values is impossible. However, for the most part, these projects have been initiated on sound bases and have been carried out by competent people following sound biological principles. This is to the credit of not only the states who originate and carry out these projects, but also to the Fish and Wildlife Service who approve them and play the role of watch-dog in these undertakings.

Most federal aid projects can be placed in one of three major categories: (1) investigations, (2) development, and (3) management. Which of these phases of fisheries work should be emphasized by any particular state is a decision that can be made only by that state. It is impossible and undesirable to attempt to establish priority of project selection on a national scale.

Some states, particularily in the Southeast, have very limited fisheries budgets. In such cases they must use their monies on projects which will provide the most tangible benefits to the fisherman. Therefore, the majority of the projects fall into the category of development and land acquisition. Little money can be used for research and investigations even if qualified personnel were available to carry out fact-finding programs. Quite often in these same states there is a dearth of desirable freshwater fishing areas and the first responsibility of the state is to provide public fishing waters. Long range investigational work is of necessity secondary.

States which have large fisheries budgets theoretically have the greatest freedom in the selection of the kind or type projects to be conducted. In these states emphasis is also being placed on that kind of project for which there is the greatest need.

One state which has sufficient state funds to carry on needed management and development activities allocates its entire federal aid apportionment to investigations, and does so because it believes that expenditure of funds for investigations is more easily justified to the public when federal monies are involved. Another state receiving maximum federal aid funds uses nearly all federal aid monies for development and land acquisition. Research and investigations were firmly established on a wide scale prior to the advent of federal aid; therefore, the additional monies from federal aid are used where there is greatest need.

However, a number of states which have adequate finances, personnel, and an abundance of fishing waters are continuing to construct more water areas and are failing to manage properly those waters they have or to conduct investigations into the problems which are paramount to the successful management of these waters.

It is believed that those persons in the Fish and Wildlife Service responsible for the approval of federal aid projects in the regional offices and in Washington should use all possible influence and persuasion to discourage the indiscriminate use of federal funds on development projects which are unnecessary or of doubtful value to the present or future fishery resources of a state.

In summation, it can be said that the basic soundness and value of the Dingell-Johnson Act is without question. There cannot and should not be established any priority plan of project selection on a regional or national scale. Each state should continue, as they have in the past, to develop their own federal aid program according to their individual needs. Investigation projects should be selected carefully, and preferably be aimed at gathering information and solving problems which have specific application in management.

If possible, even greater care should be exercised in the selection of development and land acquisition projects because these projects often require an initial expenditure of large sums of money and sometimes demand continued annual appropriations for maintenance and management.

Probably the most important single factor determining the success or failure of the present and future Dingell-Johnson program is willingness of the states (or lack of it) to hire and keep competent well-qualified professional fisheries personnel. Only with energetic professional personnel can the federal aid in fisheries programs continue to prosper.

Part 5

Business Sessions

AMERICAN FISHERIES SOCIETY

Eighty-Seventh Annual Meeting

The 87th Annual Meeting of the American Fisheries Society convened in he New Frontier Hotel, Las Vegas, Nevada, at 9:00 a. m. on Thursday, eptember 12, 1957. The agenda were as follows:

Thursday, September 12

Morning: Call to order by the President; eulogy and moment of silence in memory of Dr. Logan Bennett; Open Remarks by President; determination by the Secretary-Treasurer that a quorum was present; Address of Welcome by Lieutenant-Governor Rex Bell in behalf of the State of Nevada; presentation of names of candidates for membership in the Society; appointment of sessional committees by the President; report of Secretary-Treasurer; report of Finance Committee; report of Librarian; and reports of chairmen of Regional Divisions and Standing Committees.

Afternoon: Symposium on Problems and Programs Relating to the Federal Aid in Fisheries (Dingell-Johnson) Program; Ray Hess, Bernard Carter, O. E. Orr, and Marion Toole, participating; address entitled "Future Programs of the Bureau of Sport Fisheries and Wildlife" by Daniel H. Janzen; presentation of one technical paper. From 3:00 to 5:00 p. m. there were three concurrent symposia: (1) Future Crisis in Commercial Fishing Production; (2) Commercial Fish Farming—Problems of a Growing Industry; and (3) Watersheds and Their Conservation for Various Interests.

Friday, September 13

Morning: Symposium; Tools and Techniques of Reservoir Management; James W. Moffett, John Parsons, James T. Shields, J. Bruce Kimsey, and Gordon E. Hall participating. This was followed by presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees, election of officers; installation of new President and concluding business.

Saturday, September 14

Morning and Afternoon: fishing trips on lakes Mead and Mohave.

REGISTERED MEMBERS IN ATTENDANCE

Ball, Orville P., Cal.
Barker, Roy E., N. Mex.
Barry, James, Cal.
Beckman, R. W., Iowa
Behnke, Robert, Cal.
Beland, Richard D., Cal.
Bell, Robert R., Cal.
Boussu, Marvin F., S. Dak.
Brown, C. J. D., Mont.
Burris, William E., Tex.
Burrows, C. R., Minn.
Butler, Frank R., B. C.
Butler, Robert L., Cal.
Byrd, I. B., Ala.

Calhoun, Alex., Cal.
Callison, Charles H., D. C.
Campbell, C. J., Ore.
Carbine, W. F., Vir.
Carlander, Kenneth D., Iowa
Carter, Bernie, Ky.
Clark, Minor, Ky.
Clothier, William D., S. Dak.
Cobb, Roland H., Maine
Cooper, Gerald P., Mich.
Coots, Millard, Cal.
Cornell, J. H., N. Car.
Cottam, Clarence, Tex.

Dickson, Fred J., Ga.
Dieringer, A. Jack, Nev.
Dill, William A., Italy
Donaldson, Lauren R., Wash.
Douglas, P. A., Cal.

Eicher, George, Ore.
Eiserman, Fred, Wyo.
Ellis, C. H., Wash.
Erkins, Robert A., Ida.

Foster, Charles R., Wash.
Foster, Glen R., Neb.
Fredine, Gordon, D. C.

Gaffney, John J., S. Dak.
Galbreath, James L., Cal.
Gascoyne, D. R., Mass.
Gatlin, John C., N. Mex.
Gaufin, A. R., Utah
Gaver, L. W., Ida.
Geagan, Don W., La.
Gentry, Glenn, Tenn.
German, Eugene R., Cal.
Gordon, Seth, Cal.
Goss, Earle G., Ore.
Greene, A. F. C., Wyo.

Hall, Gordon E., Fla.
Harkness, W., Ont.
Hauck, Forrest R., Ida.
Hayford, Robert A., N. J.
Hazzard, Albert S., Pa.
Heinen, E. T., Fla.
Henderson, Croswell, Ohio
Hendrickson, E. F., Wyo.
Hess, Ray H., N. Mex.
Huddle, Howard L., Cal.
Hudoba, Michael, D. C.

Idyll, C. P., Fla.

Janzen, Daniel H., D. C.
Johnson, R. E., Minn.
Joslin, Verne E., Minn.

Katz, Max, Ore.
King, John E., Okla.
Kinney, Ed C., W. Vir.
Kolmer, Harold S., Md.

La Gue, Henry, Col.
Lambou, Victor W., La.
Langenfeld, Edward P., Wis.
Lawrence, W. Mason, N. Y.
Laythe, Leo L., Ore.
Leik, Tom, Wyo.

McBroom, James T., D. C.
McCammon, George W., Cal.
McKay, H. H., Ont.
Mair, W. Winston, Ont.
Marvich, E. S., Alaska
Meigs, Robert C., Wash.
Moffett, James W., Mich.
Mookherji, P. S., India
Moore, George C., Ga.
Moyle, John B., Minn.

Needham, Paul R., Cal.
Nenhold, John M., Utah
Nielsen, Reed S., Nev.

Orr, O. E., Neb.

Paetz, Martin J., Alberta
Parr, Sam A., Ill.
Parsons, John W., Mich.
Pautzke, Clarence, Wash.
Peck, W. L., Ore.
Platts, William S., Utah
Posewitz, John, Wis.
Pough, Richard H., N. Y.
Powell, Donald E., Wash.
Prevost, Gustave, Ont.
Purkett, Charles, Mo.

Riggs, Carl D., Okla.
Roach, Lee S., Ohio
Rucker, R. L., Wash.
Rutherford, R. M., D. C.

Schafer, Harry E., La.
Scheffer, Paul M., Cal.
Schneberger, Edward, Wis.
Schonover, Roy, Kans.
Seaman, E. A., D. C.
Shapovolov, Leo, Cal.
Shields, James T., S. Dak.
Shoemaker, Carl D., D. C.
Sigler, William F., Utah
Simpson, James C., Ida.
Skinner, John E., Cal.
Speaker, E. B., Iowa
Steen, M. O., Neb.
Stefanich, Frank A., Mont.
Stroud, Dick, D. C.
Summer, Robert, Nev.
Swenson, H. O., Minn.
Swift, Ernest, D. C.
Swift, Lloyd W., D. C.
Swingle, H. S., Ala.

Tanner, Howard S., Col.
Tarzwell, Clarence, Ohio
Terrill, Harold V., Mo.
Thompson, Fred A., Utah
Toole, Marion, Texas
Trelease, Thomas J., Nev.
Tunison, A. V., D. C.

Underhill, A. H., N. J.

Voight, L. P., Wis.
Voight, William, Jr., Pa.

Wade, Gerry, Marine
Wagner, R. A., Wash.
Wales, Joseph H., Cal.
Watkins, H. B., Alberta
Whiteleather, R. T., D. C.
Whitt, Charles R., Ida.
Wilkinson, J. T., Mich.
Wilson, Clay, Jr., Okla.
Witt, Arthur, Jr., Mo.

Zurbuch, Peter E., W. Vir.

OPENING REMARKS OF THE PRESIDENT

CLARENCE F. PAUTZKE

At the beginning of this 87th Annual Meeting, it would be well to consider the effort that has been made by the Program Committee to provide a program of wide interest. In addition to technical papers, there will be panel discussions and symposia on several special aspects of fisheries work. There is something of interest to all marine and fresh-water fisheries workers and to administrators.

During the greater part of a century that the Society has been in existence, it has sometimes been necessary to change the organizational framework of the Society and methods of procedure to allow facilitiation of its business and to provide for growth and better service to the members. Such a change was made last year at Toronto when financial assistance was voted to the Chairman of the Editorial Board. This assistance was made in recognition of the need for more prompt publication of the TRANSACTIONS and with the realization that because of increased membership the Society can no longer expect the editorial job to be handled gratuitously as it has been by many able and self-sacrificing editors in the immediate past—such editors as Ralph Hile, Lloyd L. Smith, Jr. and Kiyoshi Fukano.

The Society now has more than 1,800 members and the membership could easily double in the next 10 years; especially if present members and those who join the Society retain their affiliation. It should be emphasized that many members do not attend the Annual Meeting. To these the TRANSACTIONS, and the privilege of submittting papers to be considered for publication in it, represent the principal value received for membership dues. Such members are more apt to remain with the Society if the TRANSACTIONS is published promptly and if the papers submitted by them to the Editorial Board receive prompt and careful attention.

I am happy to say that we are now almost up-to-date on publication. Volume 86 for 1956 should now be at your home address and Volume 85 for 1955 will be mailed out within the month. In my opinion prompt publication and dissemination of fisheries information is crucial both for the advance of the Society and the fisheries profession.

In the near future, serious consideration might also be given to publication of the TRANSACTIONS more than once a year;; possibly bi-annually.

In conclusion, I hope that because of this meeting we will all be richer for new associations and knowledge acquired.

APPOINTMENT OF SESSIONAL COMMITTEES

Nominating

Willis King, Atlanta, Georgia, *Chairman*
Gerald Cooper, Ann Arbor, Michigan
Cliff Millenbach, Seattle, Washington
John Kask, Ottawa, Ontario
Richard Croker, Sacramento, California

Resolutions

Fred Thompson, Albuquerque, New Mexico, *Chairman*
Robert Meigs, Seattle, Washington
Sam A. Parr, Springfield, Illinois
Albert Hazzard, Harrisburg, Pennsylvania
Edward Marvich, Juneau, Alaska

Auditing

Hjalmar O. Swenson, St. Paul, Minnesota, *Chairman*
Paul R. Needham, Berkeley, California
Raymond E. Johnson, Minneapolis, Minnesota

Time and Place

J. Harry Cornell, Raleigh, North Carolina, *Chairman*
W. Mason Lawrence, Albany, New York
Carl Shoemaker, Washington, D. C.
Clarence Cottam, Sinton, Texas
Alex Calhoun, Sacramento, California

Publicity

Jack A. Dieringer, Reno, Nevada, *Chairman*
Richard A. Wanger, Olympia, Washington
Joseph H. Wales, Mount Shasta, California

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

Everett B. Speaker

This will be my fourth and final report as Secretary-Treasurer of the American Fisheries Society. It has indeed been a pleasure to have served this fine organization during this period. I was fortunate to have followed George Sprecher of Wisconsin who so ably administered the affairs of this office for the five years preceding my term. Mr. Sprecher left the finances of the Society in excellent condition, and I am pleased to report our house is in virtually the same order at this time.

At the close of business on June 30, 1957, Richard Paton, an accountant from the Iowa State Auditor's Office, was employed to audit the books for the Society for the four-year period just ended. This comprehensive report, together with the report for the fiscal year ending June 30, 1957, and a supplementary report to September 1, has been filed with members of your Auditing Committee. It will appear as a part of this report in the TRANSACTIONS.

There was a balance of $4,658.36 on hand in the General Fund on July 1, 1956. Receipts for this fiscal year, primarily annual dues and the sale of TRANSACTIONS, totaled $9,513.45. Disbursements from this fund, including printing, postage and supplies, reporting and clerical services, editorial stipend, travel expenses of officers, and miscellaneous expenses, totaled $3,428.61. Bank debit memorandums were $18.38. The net balance in the General Fund on June 30, 1957, was $10,724.82.

There was a cash balance on hand in the Permanent Fund on July 1, 1956, of $466.21. Receipts from life memberships and dividends from stocks totaled $200.90. Disbursements included $400.00 assistance for the Toronto meeting of the Society and $85.50 for the purchase of two shares of Consumers Stock. The net cash balance in this fund on June 30, 1957, was $181.61.

The total estimated market value of stocks held by the Society on June 30, 1957, was $1805.00, and the current valuation of the U. S. Government bonds was $11,844.00, or a total of $13,649.00 in securities held.

To summarize the financial status of the Society as of June 30, 1957, the audit shows a cash balance of $10,724.82 in the General Fund, $181.61 in the Permanent Fund, and $13,649.00 in securities held, or a total Society worth of $24,555.43.

The major outstanding indebtedness of the Society is the cost of publishing Volumes 85 and 86 of the TRANSACTIONS. It is estimated the cost of publishing these two volumes will be in the neighborhood of $13,000.00.

For many years it has been customary for the Secretary-Treasurer to submit a proposed budget for the coming year. This practice will be followed, but it should be pointed out the proposal may be subject to change pending the action of this assembly on the report to be submitted by the Finance Committee later in the program.

PROPOSED BUDGET FOR 1957-58 FISCAL YEAR

GENERAL FUND

Estimated Receipts		
Balance on hand July 1, 1957		$10,724.82
Annual dues	$ 9,000.00	
Sale of Publications	1,000.00	
Total estimated receipts		10,000.00
Estimated total		$20,724.82
Estimated Disbursements		
Printing of TRANSACTIONS—Vols. 85 & 86	$13,000.00	
Other printing	800.00	
Clerical services	250.00	
Postage and supplies	450.00	
Editing Index	150.00	
Reporting services	300.00	
Insurance	100.00	
Fidelity Bond	75.00	
Travel expense of officers	400.00	
Dues — Natural Resources Council	50.00	
Miscellaneous	200.00	
Total estimated disbursements		$15,775.00
Net Estimated General Fund Balance, June 30, 1958		**$ 4,949.82**

PERMANENT FUND

Balance on hand July 1, 1957	$ 181.61	
Value of securities held July 1, 1957	13,649.00	
Estimated Receipts		
Dividends	75.00	
Increment on U. S. Government Bonds	200.00	
Net Estimated Permanent Fund Balance, June 30, 1958		$14,105.61
Net Estimated Balance, Both Funds, June 30, 1958*		$19,055.43

*Providing Volume 87 does not appear within the fiscal year ending June 30, 1958.

At the close of the Toronto meetings last year we had a total of 1785 members in the Society. Through the vigorous efforts of Vice-Presidents Homer Swingle and Mason Lawrence, 123 new members were approved during the year by the President and Secretary. On September 5, 1957, 116 members were dropped for non-payment of dues, demit, death or other reasons. Earlier in the program 45 new members were approved, bringing our total membership to 1837.

In closing I would like to take this opportunity to thank all of the Presidents, other officers, and members whom I have served these four years for your wonderful support and encouragement. Without your assistance and patience the work would have been much more difficult.

I would also like to express our gratitude to Mrs. Thayne Wright for her prompt and efficient services. I have no doubt that the Society will continue to grow and offer more and more benefits to its members in the future.

Schedule A-1

REPORT OF RECEIPTS AND DISBURSEMENTS

July 1, 1956, to June 30, 1957

Balance on hand, July 1, 1956			$ 4,658.36
Receipts:			
Annual Dues			
Individual memberships			
for the years 1953–54	$ 4.50		
1954–55	126.00		
1955–56	454.00		
1956–57	5,643.70		
1957–58	124.50		
1958–59	11.00		
1959–60	11.00		
1960–61	10.00	$6,384.70	
State memberships			
for the years 1954–55	$ 40.00		
1955–56	60.00		
1956–57	1,400.00		
1957–58	40.00	$1,540.00	
Library memberships			
for the years 1954–55	$ 4.00		
1955–56	20.00		
1956–57	384.00		
1957–58	56.00		
1958–59	8.00	472.00	
Club memberships			
for the years 1955–56	$ 20.00		
1956–57	300.00	$ 320.00	
Sale of TRANSACTIONS and Special Publications		$ 721.75	
Sale of Index		$ 70.50	
Duplicate payment of dues		$ 4.50	
Plus: Total Receipts			**$ 9,513.45**
Balance, July 1, 1956, Plus Total Receipts			**$14,171.81**
Disbursements:			
Printing		$ 784.76	
Postage and supplies		408.38	
Reporting services (Toronto)		234.00	

Insurance	83.38	
Fidelity Bond	77.12	
Clerical services—Marj. Wright	154.49	
Clerical services—Librarian	5.00	
Editorial assistance	1,000.00	
Travel expense		
President to North Central Division meeting	345.08	
Secretary to Executive Committee meeting, Washington, D. C.	205.40	
Petty cash fund deposits for Editor	40.00	
Purchase of TRANSACTIONS	32.00	
Dues to Natural Resources Council	50.00	
Refund of dues—H. S. Davis (Honorary Member)	4.50	
Refund of dues—Receiver Gen. of Can. (Duplicate payment)	4.50	
Less: Total Disbursements		$ 3,428.61
Gross Balance, General Fund, June 30, 1957		**$10,743.20**
Less: Bank debit memorandums (See Schedule A-2)		18.38
Net Balance, General Fund, June 30, 1957		**$10,724.82**

PERMANENT FUND

Balance on hand, July 1, 1956		$ 466.21
Receipts:		
Individual Life Memberships	$112.50	
Dividend Income		
Consumers Power Co.	70.20	
Central Illinois Light Co.	18.20	
Plus: Total Receipts		$ 200.90
Balance, July 1, Plus Receipts		$ 667.11
Disbursements:		
Assistance Toronto meeting	$400.00	
Purchase of 2 shares Consumers Common Stock	85.50	
Less: Total Disbursements		$ 485.50
Net Balance, Permanent Fund, June 30, 1957		**$ 181.61**

RECAPITULATION

Net Balance, General Fund, June 30, 1957	$10,724.82
Net Balance, Permanent Fund, June 30, 1957	181.61
Net Balance, Both Funds, June 30, 1957	**$10,906.43**

Schedule A-2

RECONCILIATION OF GROSS BALANCE TO NET BALANCE FOR GENERAL FUND

July 1, 1956, to June 30, 1957

Gross Balance, General Fund, June 30, 1957			$10,743.20
Less:	1956–57 Bank debit memorandums		
	7/7/56 check returned—account closed	$1.00	
	8/21/56 check returned—drawer deceased	4.50	
	9/13/56 check returned—for endorsement	4.00	
	1/8/57 check returned—insuff. funds	4.50	

5/14/57 check returned—insuff. funds	4.50	$18.50	
Plus: Deposit in excess of listed receipts 7/20/56 Premium from Canadian bank		$ .12	$ 18.38
Net Balance, General Fund, June 30, 1957			**$10,724.82**

Schedule A-3

RECONCILIATION OF RECEIPTS TO DEPOSITS

July 1, 1956, to June 30, 1957

Total deposits per bank statements			$ 9,714.47
Total receipts per cash receipts book			
General Fund	$9,513.45		
PLUS: Deposit in excess of listed receipts (Prem. from Can. bk.)	.12	$9,513.57	
Permanent Fund		200.90	
Total Receipts to June 30, 1957			**$ 9,714.47**

Schedule A-4

BANK RECONCILIATION

Iowa State Bank
Des Moines, Iowa

Balance per bank statement June 30, 1957	$10,906.43
(No checks outstanding as of June 30, 1957)	
Balance per check book June 30, 1957	$10,906.43

Schedule A-5

SECURITIES HELD

June 30, 1957

(1) U. S. Government Savings Bonds

Number	Date Issued	Maturity Value	Value
#D682395F	8/29/49	$ 500.00	$ 424.00
#M1610061F	8/29/49	1,000.00	848.00
#D702345F	12/21/50	500.00	411.00
#M1703542F	12/21/50	1,000.00	822.00
#M1773328F	11/23/51	1,000.00	797.00
#M1773329F	11/23/51	1,000.00	797.00
#M1773330F	11/23/51	1,000.00	797.00
#M18441J	10/20/52	1,000.00	778.00
#M18346J	10/20/52	1,000.00	778.00
#M18347J	10/20/52	1,000.00	778.00
#M18348J	10/20/52	1,000.00	778.00
#M18349J	10/20/52	1,000.00	778.00
#M18350J	10/20/52	1,000.00	778.00
#M18351J	10/20/52	1,000.00	778.00
#M18352J	10/20/52	1,000.00	778.00
#M208433J	6/27/56	1,000.00	724.00
		$15,000.00	$11,844.00

(2) Consumers Power Company Stock			
#G-6085	10/3/49	28 shares @ 45¼	
#E157859	12/27/55	1 share @ 45¼	
#G164617	1/20/56	1 share @ 45¼	
#E191501	3/19/57	2 shares @ 45¼	$ 1,448.00
(3) Central Illinois Light Company Stock			
#B-1752	10/3/49	6 shares @ 51	
#B44568	4/19/56	1 share @ 51	$ 357.00
Total			**$13,649.00**

REPORT OF THE LIBRARIAN

HOWARD A. TANNER

During the period September 1, 1956 to September 1, 1957 the office of the Librarian has sold 148 volumes of the TRANSACTIONS for $470; 93 copies of Special Publication No. 1 for $23.45; 16 copies of the 1929-1952 Index for $17; and one cloth-bound 1878-1929 Index for $1.50 for a total sales of $527.75. In addition $250.75 was received from sales from the previous year and volumes were returned worth $27. An additional 19 volumes were ordered and paid for through Mr. Speaker's office and were shipped from the Librarian's office. A total of $805.50 has been forwarded to Mr. Speaker, Secretary-Treasurer of the Society, and accounts outstanding total $368. These amounts are the lowest in years and reflect the fact that Volume 85 has not yet been received. The over-run from Volume 86 was received just prior to my departure and is available for distribution. We are told that Volume 85 can be expected momentarily.

There is always a considerable number of inquiries concerning availability of back issues. For your information, there were good supplies of all the Volumes 76 (1946) through 86 (1956). Prior to Volume 76 we have limited numbers of the following: Volume 38 (1908); Volume 42 (1912); Volume 43 (1913); Volume 54 (1924); and Volume 55 (1925). Supplies of all other back issues are exhausted. Many of you will be interested to know that the Society has signed an agreement permitting the J. S. Canner Company, Inc. of Boston, Massachusetts, to reproduce on microfilm back copies of the TRANSACTIONS whenever there exists a sufficient demand.

I have continued to enjoy the assistance of a part-time librarian paid for by Colorado State University. The University asks in return that members of the Society wishing to dispose of all or portions of their library either donate to the Colorado University Library or give it the opportunity of purchasing such private libraries of fisheries material at a reasonable cost.

Our TRANSACTIONS are now well housed in a fireproof building at considerable savings in insurance costs. Other functions of the Librarian's office have generally been routine. I have already indicated to your nominating committee my willingness to continue to serve you another year.

REPORT OF THE CHAIRMAN OF THE NORTHEASTERN DIVISION

GUSTAVE PREVOST

I would like to report that we had a very good meeting in January at New Haven. Thirty papers were presented on research and management. We also had a session on marine fisheries. Next year on January 2, 1958 the Northeastern Section will meet in Montreal and we hope to have a good meeting. We will have some papers on trout and would like especially to invite those interested in trout propagation to attend. We would like the opinion of the members of the Society on our experimental work with rainbow trout in Quebec. We would like to hear about use of speckled trout on the West Coast.

Montreal might be called the "Gay Paree" of Canada and in addition to the program we will have entertainment for you at clubs, good dinner places and can even provide skiing and a snow tub-in or sleigh drive.

REPORT OF THE CHAIRMAN OF THE SOUTHERN DIVISION

J. C. FULLER

Last year the meeting of the Southern Division was held at Little Rock, Arkansas. It was well attended and a very beneficial program was presented. Several matters of special interest to our section were discussed including reservoirs and striped bass *(Roccus saxitilus)*. The next meeting will be at Mobile and we feel we will have an even better program there. *(Presented for the Chairman of the Southern Division by Fred J. Dickson).*

REPORT OF THE CHAIRMAN OF THE WESTERN DIVISION

LEWIS R. GARLICK

The Western Division of the American Fisheries Society held its annual meeting at Glenwood Springs, Colorado, June 16-19, 1957. As was the usual practice, this meeting was held in conjunction with the meeting of the Western Association of Game and Fish Commissioners. The fisheries technical sessions of the program were arranged by the Western Division of the Society. This also conformed to past practices. The Technical Fisheries papers were of excellent quality and covered a wide variety of subjects of particular interest to Western Division members. Some of the papers presented were: "Recent Progress in Fisheries Organizations and Programs" by Richard Stroud; "Some Aspects of the Ecology of Green Mountain Reservoir, Colorado" by W. C. Nelson; "Improvement of Trout Fishing in Paul Lake, British Columbia" by E. J. Crossman and "Some General Aspects of Fish Diseases in the Western States" by George Post. The business meeting reflected vigor and deep interest in the affairs of the Society. In addition to the chairman, Roy Barker was elected Vice-Chairman and Cliff Millenbach, Secretary-Treasurer. *(Presented for the Chairman of the Western Division by Roy Barker).*

REPORT OF THE CHAIRMAN OF THE NORTH-CENTRAL DIVISION

EDWARD W. SCHNEBERGER

The North-Central Division was the last of the Divisions to be organized and application for its formation was approved by the parent Society at Toronto last fall. Our first formal meeting was held last December 16 at Lansing, Michigan and we were honored at that time by the attendance of President Pautzke who gave an inspiring talk. The meeting was held as part of the Midwest Wildlife Conference and under the sponsorship of this informal organization. We had a very good program and discussions of fish research and management needs and accomplishments in the Midwest. The program included a discussion of professional standards and a Code of Ethics for fisheries workers. It was urged that a study of these important items be undertaken nation-wide. A Divisional Newsletter was issed during the year on which Dr. Carlander did an excellent job. We hope to continue this. We will meet next December in Milwaukee and you are all welcome to come.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

W. F. Carbine

Your committee is happy to report a continuation of cordial international cooperation for the care of fisheries exploited jointly by the various nations. Steady progress has been made but there still remains much to be done. International fishery commissions have been in operation for many years and we would like to express our opinion as to their importance, as follows:

1. They provide for an exchange of ideas and techniques by administrators, fishermen, businessmen, and biologists. The research requested and designed by them for obtaining answers to mutual problems meets mutual needs, eliminates national bias and prejudice, and is apt to be equally acceptable to all parties without dispute.

2. They provide for a better understanding of international fishery problems and allow closer working relationships between professional fishery workers and the fishing industry.

3. They make possible larger budgets for specific fisheries work than would be possible without international cooperation.

4. They allow more effort to be put into a specific fisheries job because each country has a vital stake in the results. Methods, techniques and equipment can be standardized; the best available used or new ones developed.

5. They require prompt publication of information and data pertaining to the fishery, because the Commissioners require such to make recommendations and regulations.

6. International Commissions provide the means for management of international fisheries on the high seas. Without international agreement and mutual adoption of sound regulation, many valuable research recommendations for improving fishing would not be put into effect. Commissions, in addition to creating goodwill, provide practical and legal means for management of high seas fisheries. There are now several action programs to which member nations represented on Commissions have contributed manpower and resources to solve fishery problems of mutual concern.

Although the principal duty of the commissions is to provide practical and legal means of managing the high seas fisheries, perhaps the most gratfying and yet undramatic development of international cooperation is the exchange of ideas possible under such an arrangement. M. C. James, esearch coordinator for the Pacific Marine Fisheries Commission, and a ember of this committee, has contributed the following illustration:

> The development of a new offshore gill net salmon fishery created alarm in the Pacific Coast states. The Pacific Marine Fisheries Commission, at its annual meeting, sparked action to bring about a coastwide ban on this fishery before it became well established. To be effective, such a prohibition should be applied equally by the three states, by Canada and by the Federal government in Alaska. Under the auspices of the U. S. Department of State, a Conference on Coordination of Fisheries Regulations took place at the end of February. Agreement was reached on the form and nature of the action required and, by the opening of the fishing season, three states had passed concurrent legislation. Canada had acted administratively, and the U. S. Government had the situation under control in Alaska.
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> Thus, a common conservation measure was made effective in a minimum of time over a vast area by informal procedures which bypassed the sometimes cumbersome machinery of normal international negotiations. The groundwork was laid for a further fitting together of Canadian and U. S. regulations and research if such action becomes desirable.

Because we believe the international commissions have been so successful, is suggested that the States enter into interstate compacts, commissions r agreements for solving fishery problems, river basin developments, avigation, flood control, and other similar problems of mutual interest.

I would like to take this opportunity to acknowledge gratefully the ssistance of the members of the Committee in the preparation of this port; especially Dr. Stillman Wright, Mr. William M. Terry, Fred E. aylor, Lloyd O. Royal, and other individuals in position to comment n international fisheries.

Following are some highlights and latest developments in International sheries:

INTERNATIONAL FISHERY AGREEMENTS

International Pacific Halibut Commission.—The high-seas fishery for alibut off the western coast of North America has been under scientific nvestigation and observation for more than 30 years. For the past 25 ears, halibut fishing has been effectively regulated by the Commission. he halibut stocks, which under unrestricted fishing, had declined to a w, and commercially unprofitable level, has been increased through ommission action by more than 50 percent and is taken with about half e former fishing effort. The catch in 1956 was more than 67 million ounds. Major work of restoring the halibut fishery has been done but here can be additional yield when the Commission discovers how to ermit it without endangering stocks. The research required is now being anned.

International North Pacific Fisheries Commission.—This Commission, hich held its first meeting in February 1954, has devoted itself primarily three lines of investigation, and has in the past 2 years made gratifying ogress.

It will be recalled that the Convention establishes a provisional line separating salmon of North America and Asian origin, and that Japan has agreed to refrain from fishing for salmon east of this line as long as certain conditions are met by the Governments of Canada and the United States. The Protocol to the Convention requires that the Commission undertake an immediate study to determine whether or not this provisional line effects an equitable separation of the two groups of salmon. The United States, Canada and Japan are cooperating in the implementation of a research program drawn up by the Commission. Major elements of the program are tagging of salmon; study of physical characteristics such as body proportions, blood types, infestations by parasites; the marking of downstream migrants; and oceanographic studies. Considerable progress has been made in all phases of the investigation. While the program is primarily concerned with the distribution and migration of salmon, a great deal of information is being obtained on the sea-life of the salmon which will be invaluable to workers in the field of salmon management.

At the request of the United States, the Commission has undertaken an investigation of the king crab stocks of the eastern Bering Sea to determine what, if any, conservation measures may be needed to make possible the maximum sustainable yield from these stocks. The United States and Japan are cooperating in this investigation.

Finally, the Commission is moving forward with the study required by Article III of the Convention to determine whether or not the stocks of halibut, herring and salmon in the eastern Pacific Ocean, which Japan has agreed not to fish, continue to meet the conditions which warrant abstention by Japan. The Commission is required to make its first determination in this regard in 1958. The United States and Canada have provided the Commission with information regarding these stocks. This information is now under study in the Commission.

The Inter-American Tropical Tuna Commission.—The Commission has continued its investigations along the lines last reported to the Society: compilation and analysis of catch statistics and related data, tuna biology and life history, oceanography and tuna ecology, and biology, ecology and utilization of baitfishes. These investigations are carried out from headquarters in California and from field stations in Panama and Costa Rica. Among the most significant of the results of this work are the Commissions conclusions regarding the effect of the fishery upon the abundance of the tuna stocks. It will be recalled that in its 1954 report the Commission reported that analysis of historical data on catch-per-day's fishing and catch-per-day's absence had led it to the conclusion that (1) the fishery for yellowfin tuna was sufficiently intense to affect very markedly the average abundance of the stocks, and (2) there is no clear relationship between fishing intensity and the abundance of skipjack tuna. Yellowfin and skipjack tuna together make up about 84 percent of the catch, yellowfin comprising about 46 percent of the catch. Continued studies of this type have confirmed these conclusions and have indicated that the level of intensity reached in 1952 and 1953 may be near that corresponding to maximum sustainable yield of yellowfin. The evidence indicates, however, that a considerable increase in the average yield of skipjack would be possible with increased exploitation.

Fishing effort decreased somewhat in 1954 and 1955 and the rate of exploitation was considerably below the level of maximum sustainable ield. Both fishing effort and catch rose somewhat in 1956, but the fishery emained at a level below that corresponding to the maximum sustainable ield.

As a result of this research, the Commission has found it possible to ake an estimate of the status of each of the tropical tuna species, taken n the aggregate, and thus is in possession of a basic management tool. The Commission is currently giving particular attention to the problems involved in formulating and applying regulatory measures against the day when fishing effort increases to the point where a limit must be imposed f the maximum sustainable yield is to be obtained.

Research on the status of important baitfish stocks indicates that with egard to the anchoveta, the most important species, the population is ubject to rather large variations in abundance not associated with the mount of fishing. It appears that in each of the major areas, at current evels of fishing effort, variations in environmental factors are of greater mportance in determining abundance than the effects of fishing.

Interim Convention on Conservation of North Pacific Fur Seals.—After protracted negotiations, which began in November 1955, representatives of the Governments of Canada, Japan, the USSR and the United tates signed the Interim Convention on Conservation of North Pacific ur Seals in Washington, February 9, 1957.

In brief, the Convention continues: (1) prohibition of pelagic sealing irst enforced internationally under the terms of the 1911 Fur Seal Convention, and continued, following the termination of that Convention in 1942, under the terms of an agreement between the United States and anada: (2) provides for a sharing of the annual kills on the Pribilof and ommandorski Islands and Robben Island; (3) provides for cooperative esearch on fur seals by agencies of the four governments to develop a asis for a more permanent agreement; and (4) establishes the North acific Fur Seal Commission, composed of one representative from each overnment. This Commission's primary function will be the planning nd coordination of research, and the development of recommendations oncerning the level and composition of annual harvest and the methods o be employed in such harvests.

At this writing, the Convention has been ratified by Canada and Japan. Ratification by the USSR and the United States and entry into force of the Convention is expected in the near future.

International Commission for the Northwest Atlantic Fisheries.—The ICNAF is a compact of 10 nations which fish the Grand Banks of the Northwest Atlantic, where millions of pounds of food fish are produced each year. Research on northwest Atlantic fishery problems is carried out by the staffs of fishery agencies of each member nation. All nations contribute to the research effort, although understandably some do much more than others. Research is planned by the Standing Committee on Research and Statistics, which routinely meets annually. Especially close liaison has been accomplished between United States and Canadian researchers because of mutual interests in ICNAF.

Mesh regulation research has occupied the Commission almost since its inception. This work has culminated in adoption of regulations by all 10 member nations for the conservation of cod and haddock stocks on the Grand Banks off United States, Nova Scotia and Newfoundland. This regulation specifiies the minimum size for meshes in nets used for cod and haddock fishing, thereby releasing young fish and taking full advantage of growth before capture. In fact, a double benefit has resulted because the new, larger mesh nets have proved more efficient for the capture of the older, marketable fish. It is estimated that 30 percent more haddock have been produced on Georges Bank since use of the larger mesh nets than would have been possible had the regulation not been adopted.

ICNAF has been responsible for much important research which otherwise would not have been accomplished. The release of statistics, the coordinated planning of research and the free exchange of information resulting from the fairly frequent meetings have all contributed to knowledge of the Grand Banks fisheries.

Great Lakes Fishery Commission.—In April 1956, representatives of Canada and the United States convened for the first meeting of the Great Lakes Fishery Commission. This organization was established in accordance with a Convention signed by Canada and the United States in September 1955. The Commission is concerned with formulating and implementing a comprehensive program for eradicating or minimizing the sea lamprey populations in the Convention area, and to coordinate research programs designed to make possible the maximum sustained productivity of the stocks of fish in the Convention area.

The establishment of the Commission made possible an improvement in operation and in coordination and planning of sea lamprey control and research in the Great Lakes. The Commission contracted with the U. S. Fish and Wildlife Service to execute the lamprey program in United States waters and with the Fisheries Research Board of Canada as the agency in Canadian waters. The entire sea lamprey control program is financed by the Commission, using funds appropriated by the two countries. The fishery research programs on the Great Lakes, although coordinated by the Commission, are directly financed by the national, state, or university organizations performing the work.

Sea lamprey control has been confined to Lakes Superior and Michigan. At the end of the 1956 lamprey spawning season, all streams entering Lake Superior known to harbor lampreys were under control. Lake Michigan should be under complete control by the spring of 1958. Lamprey control work to cover Lakes Huron, Erie and Ontario, will proceed with utmost speed.

Sea lamprey research activities have been directed toward improving existing electrical sea lamprey control devices, developing electronic devices for leading desirable fish out of lethal electrical fields, and testing specific lamprey larvicides. Tests of larvicides have progressed to the point where actual "pilot" treatment of streams is planned for the early fall of 1957. The installation and operation of 7 experimental direct-current devices in combination with alternating current control barriers proved successful in reducing fish mortality.

With the closing of the control network on Lake Superior, the Commission is immediately faced with the question of whether the stocks of lake trout remaining are sufficiently abundant to permit recovery of the fishery. It is expected that no noticeable decrease in lampreys will occur before 1959 or 1960. The lake trout will be under heavy attack during this period and the deposition of spawn during the next 4 or 5 years will be low or negligible in some instances. It is agreed by all cooperators on the Great Lakes that some hatchery planting of lake trout will be necessary. Research has indicated the size of fish to be planted and the places and time of planting, and the fact that planting can be started a year or two after control is completed. Plans are now being prepared by the Commission for the planting program that will be recommended to the federal and state governments.

Other research on the Great Lakes consist of studies on the hydrography of the lakes, tagging studies to establish population identities, movements, distribution, densities and fluctuations, adequate biological sampling and improved statistics of the commercial catch.

The Work of the International Law Commission.—After some six years of work, the International Law Commission, an agency of the United Nations, has completed its task of codification and progressive development of international law on the Regime of the Sea. In its report to the General Assembly covering the work of its Eighth Session, March 1 - July 1956, the Law Commission proposes some seventy draft articles dealing with various aspects of the law of the sea. Of interest to fishery people are the fishery articles, the continental shelf articles, and the articles on the territorial sea. All of these have a direct bearing upon the welfare of United States marine fisheries.

The fishery articles, twelve in number, are in effect a legal system designed to permit the greatest possible freedom of fishing on the high seas, and at the same time providing for the conservation of the living resources of the high seas. By conservation the Law Commission means the aggregate of the measures rendering possible the optimum sustainable yield from the resources of the seas so as to secure a maximum supply of food and other marine products. To achieve this end, the Law Commission; (1) reaffirms the right of fishing on the high seas by the nationals of all States; and (2) subjects this right to certain limitations necessary for the purposes of conservation. Thus it would impose on all States the obligation to adopt measures necessary for the conservation of resources which their nationals exploit. It would require two or more States whose nationals are exploiting the same resources to cooperate with a view to adopting by agreement necessary conservation measures. (It will be recognized that this is a procedure which the United States and Canada have for years made voluntary use of with great success in connection with the Pacific halibut and the sockeye salmon of the Fraser River.) The Law Commission would also require that in certain circumstances the fishermen of one state would be obliged to observe the conservation measures adopted by other states. It recognizes the special interest of a coastal state in the continuing productivity of the marine resources in the high seas adjacent to its coast, and would ensure the coastal state of the right to participate on an equal footing in any program of investigation and regulation of such resources, whether or not the nationals of the coastal state exploit the resource. It would also grant the coastal state the right, in certain prescribed circumstances, to adopt regulations which would be applicable to the nationals of all states fishing such resources. Finally, the Commission proposes a system of obligatory arbitration of disputes arising under the fishery articles.

To a great extent, these articles incorporate philosophy which the United States has been guided by for years. The application of this philosophy involves substantial departures from existing international law and practice but in most regards may be considered a step forward.

For the most part, the Law Commission's articles on the Continental Shelf refllect the position taken by the United States in 1945 in the so-called Truman Proclamation on that subject. The articles define the shelf as the seabed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters, or, beyond that limit, to where the depth of the superjacent waters admits of exploitation of the natural resources of the said areas; and grant to the adjacent coastal state sovereign rights over the shelf for the purpose of exploring for and exploiting its natural resources. It is with regard to the meaning of the erm "natural resources" that fishery interests become involved. The Law ommission has taken this term to include, in addition to the mineral esources, living forms permanently attached to the seabed, but not bottom sh and other fish which, although they live in the sea, occasionally have heir habitat at the bottom of the sea or are bred there. There is not nanimity of opinion on this definition in the Law Commission or among overnments. Representatives of a number of governments have proposed at the natural resources should include the entire marine flora and fauna hich lives in a constant physical and biological relationship with the abed and the continental shelf. In the past, the United States has taken position on this question of natural resources identical with that of the aw Commission.

The Commision's articles on the breadth of the territorial sea reflect e absence of agreement in the world today on this matter. It recognizes at practice is not uniform on the matter. It considers that international w does not permit an extension of the territorial sea beyond twelve miles, ut takes no decision on the question, recommending that it be settled by n international conference.

In its report to the General Assembly, the Law Commission noted the ct that there was great diversity of opinion on what was and what was ot accepted international law on the sea, and recommended that the eneral Assembly summon an international conference of plenipotentiaries deal with the matter. After some debate, the General Assembly adopted is recommendation and decided to convene a conference in March 1958 t either Rome or Geneva.

Preparations for this conference are now going forward in this Govern-ent. The Departments of State and Interior and other interested agencies re studying the articles, and in consultation with the interested public are reparing United States' position the various questions.

International Pacific Salmon Fisheries Commission, 1956—The Inter-ational Pacific Salmon Fisheries Commission has been conducting scientific nvestigations of the Fraser River sockeye salmon runs for 19 years and as been recommending regulations for commercial fishing for 11 years. hrough the application of scientific principles to the management of this ternational sockeye fishery the Commission has had outstanding success the fulfillment of its obligations. Since 1946 it has been required that ommission regulations provide equal division of the catch of Fraser River ckeye insofar as practicable. In the past 11 years United States fishermen ave caught 18,008,893 sockeye and Canadian fishermen 18,421,157 sock-ye, a cumulative difference in equality of about 0.5 percent for the entire riod. Commission regulations and management principles, together with moval of river obstructions, have almost doubled the commercial catch sockeye over the past 8 years. In the 4 years ending 1956, the total catch sockeye was 17,469,899 fish, whereas in the preceding 4 years it was

8,885,768 fish. Research has indicated the intimate relationship between sockeye salmon and their fresh water and ocean environment. Such research has enabled the Commission to rehabilitate barren streams by transplantations of eggs from suitable donor stocks. In addition, it has provided the basic principle for protection of the fishery from possible adverse effects of multiple water use such as water pollution and power dams. Protection of the fishery from such adverse effects requires increasing attention by the Commission each year. Management of the fishery is also becoming more complex due to increased numbers of fishing gear and the increased efficiencies and effectiveness of the gear.

FOREIGN AID PROGRAM

The International Cooperation Administration continued to carry out programs of technical assistance in the development and conservation of fisheries in several foreign countries. Although fish add only a small fraction of the total supply of food in the world, they are important for contributions of protein, minerals, and vitamins. It has been estimated that fish supply, on the average, only 10 calories and 1.3 grams of protein per capita per day for the world population. Marine resources in general can be exploited further without danger to the supply. Additional consumption is particularly important in part of Asia, where the predominantly rice diet require additives for proper balance.

During the past year or somewhat more, fishery programs were in force in 10 countries. The countries and principal technicians assigned to them are listed below:

El Salvador	Charles B. Wade
Peru	Robert O. Smith
Liberia	Charles Jones
Pakistan	Leroy S. Christey
India	Ole J. Heggem
Indonesia	Edwin H. Dahlgren
Thailand	Milton J. Lobell
Viet-Nam	Robert J. Schoettler
Taiwan	William A. Ellison
Korea	Harry E. Timmis

An important part of the program is that of training students and adminstrators of foreign countries in the United States so that they can assume responsibility for continuation of projects started by American technicians. Each year, several participants received instructions or in-Service training and return home to make practical use of their new knowledge and skills. In the last few months of 1957, trainees will arrive from Indonesia, Thailand, Korea, India, and Pakistan, to add to the growing body of competent technicians in various fields of industry, biology, and management.

The U. S. Fish and Wildlife Service works closely with the International Cooperation Administration in carrying out the foreign aid program. The Service assists particularly in recruiting technicians for assignment abroad, in providing technical support, and in arranging suitable training facilities for foreign students.

International Events in Central and South America.—The 1956 meetings of the Gulf and Caribbean Fisheries Institute and the International Game Fish Conference were held in Nassau, Bahamas. The 1957 meetings are both scheduled for November in Miami Beach. At the Nassau meetings reports were presented on the sport fishing situation in the Virgin Islands, game-fish of Bermuda, pelagic game fishes of Chili, the commercial fishing industry in Cuba, the research conducted on the marine fisheries of Yucatan, Mexico, and means of improving the Caribbean fisheries.

In Venezuela, government and private organizations are promoting the development of the fisheries by training marine scientists for this work. Two students recently completed training in the United States. Panama, in an effort to develop her shrimp fishery, has obtained an FAO expert to make a study of the fishery. Mexico is increasing its interest in the shrimp fishery and plans to set up a research agency. The Shrimp Association of the Americas, which is a trade association including the United States and Mexican shrimp producers, has been active in supporting fisheries work and has established two fellowships to support graduate students in fisheries at the University of Miami.

The shrimp fishery on the Tortugas grounds near Key West has recently become an international one with the advent of Cuban trawlers. In recognition of this, some preliminary discussions have been held concerning the desirability of an international treaty.

Your Committee urges this Society to continue to take the lead in supporting the practice of seeking the solution of international problems through international investigations.

COMMITTEE ON NATIONAL-STATE RELATIONS

Richard H. Stroud

Mr. President, and fellow members of the American Fisheries Society, I find that the National-State relations are in a generally dull and impassionate state. I was warned a year ago that this is a dull subject and no matter how I might try I couldn't change it. After reading some past reports I am forced almost to agree, and warn you that my report will not depart seriously from tradition.

Few states seem to appreciate as yet the potentially helpful role that the federal agency — the United States Fish and Wildlife Service, and especially its new Bureau of Sports Fisheries and Wildlife — can play in relation to the states. But, with passage of the Fish and Wildlife Act of 1956 and the subsequent and continuing reorganization of the Fish and Wildlife Service, I feel that we stand on the threshold of a new era in national-state relations.

Plans are afoot that may result in a significant expansion on the part of federal agencies in the sport fishery field. This event, when it materializes, will involve new phases of federal-state relations. No matter what problems may arise, however, I am confident that we, like the eternal Britishers, will "muddle through" satisfactorily.

Indications are that the new federal program will feature greatly extended effort in research on both fresh and saltwater sport fishery problems. As I understand it, too, certain types of management activities on Federal lands may be expanded. Extension services may be made available. Increased technical assistance will become available to the states. It is in this province that there will be frequent inter-agency contacts.

I am supremely confident, based on the fine character of the top personnel in the Bureau's new Division of Sport Fisheries, that the states will be pleased with these developments. I am most definitely assured that every possible effort will be bent toward this end.

Mr. Ross Leffler, Assistant Secretary of Interior for Fish and Wildlife, has also personally assured me, that the Service will undertake to provide financial assistance to help train professional sport fishery workers. This should be a big help in providing needed biologists for both state and federal programs. It could well prove to be one of the more significant services to be made available.

Casting about for something worth your consideration and that of the committee, this seemed as profitable a question as any: How can federal hatcheries best serve the states? Is present practice satisfactory?

This came to mind, too, because of a rash of bills before Congress last year to build new hatcheries here and there. The Service floundered. Did they want them? Were they needed? Should the Federal further invade states' prerogatives in the management field?

The Honorable Herbert C. Bonner, Chairman, Merchant Marine and Fisheries Committee, U. S. House of Representatives, commented on the number of hatchery bills. He said, in part:

> "It seems desirable . . . that the subject be thoroughly explored in the first session of the next Congress to examine the policies of the Fish and Wildlife Service regarding the location of hatcheries, their overall need, and the formulation of standards by which applications for new hatcheries can be evaluated on a national basis."

The several members of the National-State Relations Committee were sent copies of a mimeographed document, dated May 12, 1949, entitled SERVICE POLICY REGARDING HATCHERIES, for review and comment. My thought was to see what helpful suggestions could be made, for possible guidance to both Mr. Bonner and Mr. Leffler.

In brief, these are the principles upon which the policy statement holds that Federal fish-cultural work should concentrate:

> (a) Production of sport species for stocking Federal lands (such as National Forests, National Parks, Indian Reservations, Wildlife Refuges and Reclamation Resources.) The federal agencies have held that state resources often are insufficient to manage other public waters properly because of lack of income, personal, or for other reasons.
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> (b) Production of warm-water species for stocking farm ponds, impoundments, and public waters. Present supply from State and Federal hatcheries is inadequate.
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> (c) Production of trout for trout waters. These colder waters are not so fertile as warmer waters inhabited by bass. There is a constant decrease in the amount of trout waters and a concurrent increase in the number of trout fishermen. The Federal has held that legal-sized fish beyond hatchery capacity are needed for this program.
>
> (d) Provision for an integration of Federal and State propagation of sport and/or commercial species in states where cooperative and joint operations are necessary to provide adequate stocking resources, such determinations to be based upon agreement reached with the fish and game department of any state concerned.
>
> (e) Operation of experimental hatcheries for purpose of improving methods of propagation and distribution and for training personnel for Federal, State, and commercial operations.
>
> (f) Operation of units constructed by Federal Government to offset damages caused by Federal river-basin projects (*e.g.* Columbia Basin, Missouri Basin, Central Valley). Question of state operation may be decided according to individual circumstances prevailing at each project.

The majority of this Committee (the federally-employed members withheld comment) expressed surprise and interest in and lack of prior knowledge of the existence of the Policy Statement. After study, however, majority agreement was reached concerning a number of these points of policy as listed above. It was felt that the state fish hatcheries are doing a much better job now at least than the Federal agency credited them with in 1949.

The urgency for the Federal Service to stock Federal Lands seems greatly diminished. At the least we cannot forsee the need for any federal hatcheries to supply resident species of fish except where federal construction projects create potential fishing areas that both require stocking and are beyond the present capacities of the states to stock.

And we believe that reemphasis is needed that it is wasteful and/or futile to undertake maintenance stocking of warm-water species in impoundments. Therefore, every proposal for a new federal hatchery for stocking such waters should receive the most stringent scrutiny with this in mind.

Fishery technicians and administrators alike have expressed wishes for federal funds to construct and operate hatchery facilities to meet justifiable annual requirements of newly created waters. At the same time, it is evident that the state agencies want to retain full control of policy matters pertaining to species to be raised and when and where the fish would be planted.

There is little doubt but what added hatchery facilities will be needed to offset losses of anadromous fish. At this particular time no one can forsee just what will be the ultimate requirement. There are many factors to be considered, of which economics is of primary importance and will decide the future limitations.

The fish application system for stock to be planted in private ponds is out moded. We believe it should be rapidly curtailed until abolished altogether. We fail to see significant legitimate justification for its continuance. It conflicts head on with state policies and operations. We are inclined to view it as an unwarranted opportunity for political interference in modern fish conservation programs.

Most applicants could fill their requirements from private hatcheries or under cooperative agreements from state hatcheries. We see no reason why the private individual should pay for fish he wishes to use privately—or open his water to public use if supplied from a government-operated facility.

Several members of the Committee feel that the Service should not handle fish for the National Forests and Reclamation Resources while the states have the responsibility for legal control of, and facilities for managing the waters. Watersheds are not limited by Forest boundaries; management is a prerogative and a responsibility of the States.

We firmly hold that the stocking of State waters from Federal hatcheries should be done only at the request of and as part of State programs. In this regard, we are pleased to report that in most states all stocking is done under cooperative programs. We feel it would be a further improvement if state personnel did the actual stocking. Federal hatcheries should be used to supplement State facilities for improved efficiency in certain areas.

Two reasons have been advanced for not permitting a free-lance Federal trout program in the States. They are: (1) the absence of an adequate management staff to pattern a program with that of the States; and (2) an alleged inability of Federal hatcheries to produce a suitable product. A few states appear to have established rigid standards for the hatchery product. Trout produced by Federal hatcheries are said to have fallen way below these standards in at least a few cases.

A number of responsible state employees have expressed this principle: "Since resident fish within the boundaries of the State are the property of the State, responsibility for maintenance of the resource through hatchery production should be a function of the State." Where fish hatcheries are needed, except in the special circumstances noted above, the states should build and operate them.

Federal Hatcheries can serve well in such functions as fish cultural research and improving broodstocks. The Federal program can also be of some further value to supplement State programs but *only* at the discretion of the States.

It has been suggested at times that the Federal hatcheries should be turned over to the states to operate. We are convinced, however, that they would only prove to be "white elephants", in this event, unless sufficient funds were also turned over for annual operations and maintenance. Other considerations would also act to deter acceptance by the states. Nevertheless, we recognize that many responsible people question whether the Federal government should be in the hatchery business at all.

EDITORIAL BOARD

John B. Moyle

The formal report of the editorial board will be short for the real report of this board is the published Transaction. Volume 86 of the Transactions for 1956 was mailed out the last week in August and is now in the hands of the members of the Society. This volume includes 39 papers and other material for a total of 540 pages. It is the result of the efforts of many people in addition to the authors themselves. The editor wishes to thank them all and is especially grateful to the associate editors who gave of their time to referee, review and comment on the papers submitted for publication.

The editorial job of preparing a volume of the Transactions is considerable and amounts to about a half-time job for the editor, a fourth-time stenographic job plus a lot of help from associate editors. This load could be lightened somewhat by the authors themselves if they would do the following things: (1) read the instructions to authors which are printed in the Transactions and follow them; (2) condense their papers, remembering that the Society has about 1,800 active members and space in the Transactions is limited; and (3) be prompt in returning manuscript and proof; individual procrastination may delay publication of an entire volume.

If the Transactions are to come out on time, it is necessary to have a deadline for the submission of papers to any volume. The deadline set for Volume 87 is December 15. Of course, the editorial board will be happy to receive papers at any time, but it is likely that those received after December 15 will be held for Volume 88.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

P. A. Larkin

In the past year your Committee has attempted to review progress in several specialized fields that relate to the broad subject of hydrobiology and fish culture. In each case the topics were those which were close to the interest of a particular committee member. Thus while our committee report may suffer from breadth of coverage it provides informed assessments in a few fields. This is a pattern of activity that has been suggested by previous committees which we would recommend to our successors. It gives the committee members assignments that they can handle with relative ease, and over a period of years will provide complete coverage of the whole field of hydrobiology and fish culture.

There are five reviews of recent progress in the committe's report: Benson on water fertilization, Everhart on fish and fish passage, Rucker on fish diseases, Stevens on fish culture, and Stevenson on farm fish ponds.

Benson's review deals with progress in water fertilization since 1953. Mention is made of the possibilities of control of noxious aquatic plants that have been indicated by recent work in Ohio. Fertilization of Alaskan inland lakes to increase production of immature salmon is discussed. Progress is noted in the correlation of soil types and suitable water fertilizers in the southeast. New techniques of applying fertilizers slowly to the water layers of maximum productivity and the use of liquid fertilizers are mentioned as improvements which may find wider use. Several recent studies have suggested the need for preparing natural waters for fertilization by changing pH of the water as a preliminary to application of fertilization. Stream fertilization in Tennessee has given encouraging results and may be a useful method of increasing production of anadromous fish.

Most significant in Benson's review is the discussion of the long term effects of fertilization. Many biologists have voiced concern about the artificial eutrophication of natural waters, especially since there is apparently a considerable amount of unwarranted fertilization. Recent reviews in limnological journals that deal with the mechanics of aquatic production should be used as a basis for planning fertilization research projects. It is concluded that fertilization techniques are improving and as a tool fertilization is now more useful to aquatic biologists. However, as methods are devised to funnel production into desirable species and size groups, fertilization may be unnecessary in many cases where it is presently practised or contemplated.

Everhart also underlines the need for considering basic biological problems in the development of techniques of passing fish in rivers obstructed by power dams. After listing the types of effects that obstructions have on anadromous fishes, Everhart emphasizes opinion that basic research on the fresh-water requirements of migrating fishes will be necessary before conclusions can be drawn as to the complete effects of a proposed installation. Recent progress in designing bypass structures for young fish, and in design of fishway facilities for adults are reviewed. The conclusion is then drawn that even greater efforts must be made to organize imaginative programs that are backed with facilities and resources of results commensurate with the magnitude of the problems that are to be attained.

Fry's review provides a sober assessment of the slow but accelerating progress that is being made on tackling the very problem that Everhart's review poses. The description of the environmental requirements of anadromous fish in fresh water is largely centered on quantitative knowledge of environmental physiology. Recent work and work in progress on fatigue, respiration, temperature tolerance, acclimation, tolerance limits to toxic substances, and similar researches are all providing much understanding of when, where, how, and why fish will be affected by changes to environment. Progress in these fields is slow, but encouraging.

Rucker deals briefly with progress in fish diseases both nutritional and pathological. He mentions steady progress in understanding of nutritional requirements of fish and holds out the hope that eventually cheap adequate diets can be formulated. The need in many cases for supplementing pellet foods with unheated meat or fish products is touched upon. Two relatively new diseases are singled out for the attention of all of us—first "kidney disease" caused by the organism *Corynebacterium*, second "fish tuberculosis" (so called) an acid-fast organism for which no control measures are known.

Stevens has noted several recent advances in fish rearing techniques. Automatic feeding devices, the increased use of aluminum and plastic, the use of tray incubators for eggs, selective breeding and special feeding for coloration are all singled out for mention.

Stevenson has summarized recent work of the Arkansas Game and Fish Commission which relate to production of warm-water pond fish, especially catfishes.

The strongest note in the committee reports as a whole is the need for increased emphasis on research aimed at study of basic mechanisms—whether production in aquatic environments, environmental physiology, fish behaviour, fish nutrition and disease or warm-water pond production. Most fisheries agencies recognize three basic phases of their work; protection of stocks from effects of other resource development, management of stocks on hand, and improvement of environments and fish populations to attain higher production. In all three fields there is always need for the slow but complete studies of aspects of the biology of fish and their environment. It would seem that this need is better recognized than ever before. Although it is often suggested that universities may provide the best atmosphere for this basic work, it is increasingly clear that government agencies are not only tackling basic work themselves but are encouraging university interest in specific types of basic research that are timely and often urgent.

RECENT PROGRESS IN WATER FERTILIZATION — *Norman G. Benson*

In recent years many fishery workers have looked to water fertilization as one method for increasing stocks of both sport and commercial fish. This report consists of a general review of progress of fertilization research and management since 1953. An excellent review of the literature on artificial fertilization was completed by Maciolek (1954), and no attempt will be made herein to repeat information covered by his report. Many of the facts presented here have been gathered through personal correspondence, and only certain references will be cited.[1] Subjects to be covered are: (1) treatment of large lakes to control noxious aquatic plants; (2) fertilization of Alaskan inland lakes to increase the survival rate of immature red salmon; (3) correlation of soil types and water fertilization; (4) use of new techniques in fertilizer application; (5) use of concentrated forms of fertilizer; (6) preparation of natural waters for fertilizer application; (7) fertilization of warm-water streams; and (8) appraisal of fertilization practices.

In Ohio natural lakes have been fertilized to control higher aquatic plants. An increase in fish production was a secondary purpose although one lake showed 100 percent increase in anglers' catch. This type of program presents many possibilities for glacial-formed lakes which possess large area of shallow water for the encouragement of higher aquatic plants.

In Alaska, Bare Lake which is used naturally for the rearing of immature red salmon has been fertilized to increase the survival rate (Nelson and Edmondson, 1955). It was believed that the ocean could support a greater number of salmon than presently survive in such fresh-water lakes and migrate to the ocean. Prior to heavy commercial fishing, large numbers of adult red salmon died after spawning to supply the nutrients which were added by inorganic fertilizers in this experiment. Increased plankton production resulted, and the salmon migrating from the lake to the ocean were longer and heavier than in previous years. Recent unofficial reports on this work indicate that Dolly Varden trout have increased in numbers and their predation on immature salmon may offset the gain in survival rate due to the fertilizer.

Research has been conducted on the relationships between different soil types and various pond fertilizers in Georgia and Missouri. Some of this work has shown that phosphorous is the only deficient element in many waters. It is hoped that eventually pond fertilizers can be recommended with as much confidence as are soil fertilizers sold to farmers at the present time.

More efficient methods for fertilizer application have been developed. In Missouri experience has shown that many of the nutrients which have been added to water become bound in bottom soils and higher aquatic plants thus becoming unavailable to plankton, and thence fish (Walker, 1956). In Missouri fertilizer is applied in ponds by devices that distribute it slowly in the water layer of maximum productivity. The idea is to release only as much fertilizer in the water as can be utilized by plankton immediately. There has been an increased use of high analysis and liquid fertilizers, *e.g.*, 20-20-5, in Georgia and Missouri. In Georgia it was estimated that half of the ponds are fertilized with concentrated fertilizers such as 20-20-5 (Howard Zeller, personal communication). With these concentrated fertilizers less bulk is involved in application, and it is believed that the essential elements such as phosphorus and nitrogen are utilized more efficiently.

Several states have found that some natural water is not suitable for the efficient utilization of inorganic fertilizers. In Georgia biologists have found that lime and basic slag raise the pH of acid water adequately. Asia fishery workers (Villadolid, *et. al.*, 1954) have found that it is desirable to keep the pH of water around 7.8 to get the best utilization of fertilizer by plankters. Lime was used to reach this pH. The above paper mentioned that this pH is close to the constitutional pH of cell nucleii in plankton.

In Tennessee a method of stream fertilization has been developed for a warm-water stream which regularly becomes a series of isolated pools in mid-summer and fall. In this work rough fish, predominantly carp and buffalo, benefited more than did game fish, although the catch of game fish doubled. There was a definite increased production of periphyton, which in turn resulted in an increased bottom food production. It was also learned that the survival rate of certain stream species could be increased when the fertilizer was added about two weeks prior to the time when the fry absorbed their yolk sacs. This type of fertilization might have practical value on the management of anadromous fish where the survival rate in streams is low due to lack of food.

During the last few years some biologists have been concerned about the over-eutrophication of our natural waters. If we encourage fertilization too much, we may make waters which are presently suitable for salmonids and unsuitable in a relatively short period of time. Edmundson (1956) showed that domestic sewage caused rapid eutrophication in Lake Washington. Fishery biologists should be cautioned about increasing production without considering the future effect on the fish species of composition. Another problem is that the aesthetic values of fishing in clean, clear waters have sometimes been rated as high or higher than the catch itself. Many anglers do not like the green water commonly associated with fertilization.

Fertilization has been encouraged in many waters where the fishing pressure has not warranted an increased production. This fact has been especially true on some private ponds. Field investigations in Kentucky (Smith *et al.*, 1955) and Alabama (Moss and Hester, 1956) have shown that few pond owners fertilize their ponds regularly enough to gain many benefits. Much fertilizer was wasted on unmanageable and unbalanced fish populations. Whenever the standing crop of fish is made up of large numbers of trash fish species, it is usually uneconomical to apply fertilizer.

Some recent work has been presented on new methods of describing the mechanics of aquatic production (See Symposium on Primary Production, Limnology and Oceanography, Vol. 1, Nov., 1956). Many of the ideas presented should be incorporated into fertilization research projects. More attention has been paid in the last few years to fish population manipulation, such as reclamation, than to increase the water fertility. As methods are devised to funnel our available aquatic production into desirable fish species and size groups, fertilization would be unnecessary in many cases where it is presently being practiced or contemplated.[1]

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IMPROVEMENTS IN FISH CULTURE — *Richard I. Stevens*

Spurred by efforts to attain great production goals, fish culturists are rapidly adopting equipment and methods of other branches of animal husbandry, improvising new apparatus and applying new techniques and materials to their rearing operations to lessen food and labor costs.

New York and Wisconsin have developmental work proceeding on design and operation of mechanical and automatic feeders. In New York, Haskell has perfected a compressed-air feeder that broadcasts, in pre-measured quantities, finely divided fresh meat to fingerlings in ponds. Wisconsin workers have tested production equipment which automatically feeds pelleted food to trout.

In the handling, loading and inventory operations, apparatus which have proved of potential value are mechanical conveyers and bladeless pumps for transferring fish, and an electronic counter for enumerating small fingerling. Volumetric measurements are being increasingly used in shipping-weight determinations.

Because of its light weight and resistance to corrosion, aluminum has found a place as a construction material. Do-it-yourself screening materials have been assembled as trough screens. Distribution tanks and rearing troughs have been constructed of sheet aluminum and are valued because of their low up-keep and durability. Portable graders of plastic and aluminum are in use as well as vertical egg incubators of the same materials. It is even forecast by some that rearing troughs are on their way out since the advent of the Burroughs-type incubator. In this, eggs are hatched and fry allowed to "swim-up." Fry are transferred directly to raceways or tanks.

Emphasis is being diligently applied to the improvement of the quality of the hatchery product. Studies, incorporating techniques and procedures long used in plant breeding, are in progress in at least two states to develop pure strains of trout that have attributes both of aesthetic value and resistance to disease. An eastern state routinely effects desirable coloration in stock trout by putting its hatchery fish on a special feeding regime before stocking them.

FISH AND FISH PASSAGE — *W. H. Everhardt*

Should fishery biologists be optimistic or pessimistic regarding the future of fisheries that must share water ways with dam building and dam operating interests? Perhaps we can only be realistic. Consider the changes imposed by the proposed Moran dam on the Fraser River with a 720-foot head, a construction period of five years, a 165-mile long reservoir, and temperature differentials estimated at 10° F. between subsurface tailwater release and reservoir surface. Spawning and rearing grounds, an estimated 1140 lineal miles, were cut off by 350-foot Grand Coulee dam that meant the end of salmon in the upper Columbia River. The East Coast problems of both

United States and Canada may be small when compared with those of the West, but the Maine Aroostook River with its 1632 miles of tributary streams has 70 man-made obstructions to fish migration. The problem of evaluating fisheries and presenting cost figures to compare with the exact costs submitted by engineers for a kilowatt of power is familiar to all. The fisheries of the Fraser River have recently been evaluated at $52,000,000 annually yet, "based on present evidence one must conclude that there can be no such thing as fish and full power development on the Fraser River."

The impact of obstructions on migratory fishes, particularly anadromous species, is obvious when the following effects are considered:

1. Low discharge may discourage adult fish from leaving the estuary or moving upstream into fresh water.
2. Quality of the fresh water may be changed by increased temperatures, reduced flows, and the addition of sewage or industrial wastes. These changes affect the adults moving up to the spawning grounds and the young fish moving downstream.
3. Diversion of normal flow from natural channels may lead migrating adults or young into "blind alleys" or, at the least, delay the migration.
4. Blocked passage, even though fish passage facilities are provided can result when fishways are inadequate and poorly designed. Young fish moving downstream must pass over, or through, the dam frequently suffering high mortalities. Collecting systems and bypasses are yet to be designed for large installations.
5. Reservoirs may flood-out spawning and nursery areas and they surely will change the water quality. Changed water quality may influence the young as they move downstream, even to the extent of eliminating them.
6. Predation becomes a problem in tailraces where the weakened migrants are exposed to large concentrations of predators.

Few fishery biologists would experience any difficulty in naming rivers to illustrate the above effects of obstructions.

There seems to be unanimous agreement among various fishery agencies in Canada and United States that the solution to the problems lies in research. Unfortunately only meager funds and facilities have been available and this big problem needs solving in a hurry if the results are to be utilized in the increasing number of water development projects. Some encouragement may be justified in the increased interest of the sport and commercial fishing industries and support that is being offered by indvidual angler.

Ideally a complete understanding of the fresh-water requirements of the migrating fishes would be necessary before conclusions could be drawn as to the complete effects of a proposed dam installation. This research would be basic; the kind usually best performed in an academic surrounding. Delays in migrations and the changing water quality would effect the physiology of the fish, and rates of metabolism would change. Field observations substantiate that fish having finally run the gauntlet of obstacles may be too weak to reach the spawning grounds, or, once there, too weak for efficient reproduction.

A beginning has been made in the study of by-passes with the use of electricity, bubbles, moving cables and chains, and more recently a system of louvres. These preliminary studies have served to emphasize the complexity of the problem. Different species react differently, a complication the biologist would expect, but one that magnifies the problem. Fluctuating forebay and tailrace levels add to the complexity. Perhaps as more is learned about repellants they will be of value in guiding fish away from dangers and into collecting devices. Spillway design will influence the survival of young fish passing over the dam.

Fishway design must be studied systematically as the Bonneville laboratory of the U. S. Fish and Wildlife provides. This laboratory is essentially a big flume in which paired full-scale segments of fishways can be built. Migrating fish are diverted from the main fishway into the experimental fishways where various tests can be performed and the reactions measured. The importance of this phase of the fish passage can be emphasized by the cost figures of $306,000,000 to construct fish facilities for the contemplated 10 power dams on the Fraser River and its tributary, Thompson River. These cost figures are estimated by comparison with Columbia River installations. Even with this expenditure it is estimated that 80 per cent of the Thompson River migrants and 48 per cent of the upper Fraser River migrants would be killed in passage over the spillways and through the turbines of the dams. This mortality would reduce the number of returning adult sockeye available to the commercial fishery by 73 per cent.

The need then is evident. More facilities and resources are necessary to provide a research program commensurate with the magnitude of the problems of fish passage. Such a project seems almost exactly the type that the newly reorganized U. S. Fish and Wildlife Service should consider in the Task Force Report. Here is an opportunity for an imaginative organization to design a coordinated effort with sufficient backing to guarantee successful results. Other governmental agencies have the same responsibility.

The following agencies were contacted for opinions regarding the future of fish passage and all responded with helpful, detailed letters and publications.

Fisheries Research Board of Canada
Canadian Department of Fisheries
British Columbia Game Commission
University of British Columbia
International Pacific Salmon Fisheries Commission
United States Fish and Wildlife Service, Pacific
Salmon Investigations
Maine Department of Inland Fisheries and Game

RECENT PROGRESS IN CONTROL OF FISH DISEASES — *Robert R. Rucker*

Mortalities among hatchery fish are still a limiting factor in production. Spawning techniques and the handling of eggs and fry are considered satisfactory, but definite information on the nutritional requirements of fish is still lacking. Diets compounded by hatcherymen from cheap and easily available materials may be deficient in certain essential factors and thus be the cause of losses. Work is progressing on determining the vitamin, protein, fat and mineral requirements of salmon and trout, which should eventually make it possible to formulate cheap adequate diets. A number of commercial pellets for fish food have been produced, but in many cases at this time, such a diet must be supplemented with unheated meat or fish products in order to maintain the fish in good health.

Two diseases of salmon and trout, both known in Europe, seem to be coming more predominant in the United States. This may merely reflect better recognition. One disease called "kidney disease" is caused by an organism belonging to the genus *Corynebacterium*. This disease can be limited by the continual use of sulfonamides but is actually not eliminated. Salmon infected with "kidney disease" have been planted and have produced good returns, but generally the disease develops slowly and takes a high toll. The second disease is caused by an acid-fast organism, and in the literature is referred to as fish tuberculosis. This disease also occurs in wild and hatchery populations but no control measures are known. These problems and others caused by organisms similar to viruses and the pseudomonads, as well as mycotic and protozoan agents are being investigated throughout the United States.

REARING OF BUFFALO FISH AND CATFISHES — *James H. Stevenson*

There is considerable interest in the South-Central States in pond rearing of buffalo-fish *(Megastomatobus cyprinella* and *Ictiobus bubalus* and *I. niger)* and the large catfishes, especially channel catfish *(Ictalurus lacustris)*. The fish are commonly reared in ponds and reservoirs as a complementary crop in areas producing rice *(Oryza sativa)*. During the past five years in Arkansas, hundreds of requests have been received concerning the commercial possibilities of such fish rearing, and many such enterprises now in operation have been visited. Two aspects of this specialized fishery will be considered; (1) facilities necessary for commercial raising of buffalo-fish and catfish and (2) methods for propagation of channel catfish as developed at Arkansas' State Fish Hatcheries. Information on the former was supplied by Andrew Hulsey and Lee Brady of the State Fish Hatchery at Lonoke, Arkansas, and on the latter by Bruce Crawford of the State Fish Hatchery at Centon, Arkansas.

Commercial raising of buffalo fish and catfish

Best results in commercial production have been obtained from ponds where a combination of buffalo-fish and catfishes was used. In addition to channel catfish, blue catfish *(Ictalurus furcatus),* white catfish *(Ictalurus catus)* and flathead catfish *(Pilodictis olivaris)* have received limited use.

The most satisfactory ponds are usually under forty (40) acres in size. Larger ponds suffer more from wind action which muddies the shallow water. Too frequent muddying results in substantial loss of production. The levees impounding a large reservoir which is not wooded are severely eroded by waves, resulting in frequent maintenance costs. Levee banks are protected by planting native grasses. Best results are obtained when a levee stands for a year to stabilize before the pond is filled. The better ponds have at least 18 inches of water in their shallowest parts, otherwise difficulties are experienced with too high water temperatures, heavy weed (moss) growth and predation, especially from herons.

On flat lands where construction requires excavation, the borrow pit should be inside the reservoir adjacent to the levee. By making all but one of the borrow pits wide and shallow, and by ditching the bottom of the impoundment, where necessary, the water is made to drain into a deeper borrow pit on the lower side. This procedure allows easy concentration and harvesting of fish.

Ponds are usually constructed during the summer, and as soon as the rice is combined are made ready for fish. It is best not to fill new ponds immediately with well water as this is both expensive and encourages weed growth. It is usually adequate to fill borrow pits and ditches the first few months, fertilize and plant the fingerling fish in them. The pond can then be filled later, during the winter, with well and rain water.

Stocking is usually done in late summer, fall and winter at rates of 30 to 100 fingerlings per acre for buffalo fish and 20 to 75 fingerlings per acre for catfishes; the specific stocking rate for any pond depending upon natural fertility and plans for fertilization. There are now several commercial operators producing fingerlings for such stocking.

The ponds are usually operated on a 1- to 3-year schedule, with 2 years being average. It is important that no foreign fish have access to the pond, at least the first year. This is a common cause of trouble. The presence of foreign fish in the second or third years is not so damaging. Turbid surface waters can sometimes be introduced into the ponds advantageously to control weed growths, but too much turbidity is undesirable.

Ponds are usually not fertilized the first season, there being enough fertility in flooded crop stubble and residue, but during the second season, fertilization may be desirable. Usually fertilizers are added with the following crop of rice in mind. Extreme caution is necessary to prevent building up too much nitrogen. Harvesting can start the middle of the second season, and one-fourth to one-third of the fish can be removed with traps, seines or nets. At this time, the buffalo fish range in weight from 4 to 6 pounds. This, however, is a "bonus" crop that may help pay for the fertilizer and other expenses. For final cropping, the pond is drained usually 20 to 24 months after stocking, and ordinarily 200 to 1000 pounds of fish per surface acre are harvested. It is generally advantageous for the owner to harvest in summer or winter, when the supply of fish from public waters is low. Usually buffalo fish sell for 15 to 20 cents and catfish for 30 to 40 cents per pound.

Reports from pond operators indicate that 90 percent of stocked buffalo fingerlings, but only about 50 percent of the catfish fingerlings, survive to be harvested. The goal is to obtain 6-pound buffalo fish and 3-pound catfish for sale.

Raising channel catfish fingerlings

Because of the great interest in raising channel catfish fingerlings and the inadequacy of the literature, it seems desirable to describe the method used at the State Fish Hatchery at Centerton, Arkansas.

Spawning pens, artificial nests, rearing troughs and culture ponds are used to produce 4 to 8 inch fingerlings for stocking. Spawning pens 5 to 6 feet wide and 10 to 12 feet long are placed along the shore of the pond where the bottom slopes gradually and at a maximum depth of 30 inches. The pens are constructed with wooden frames of 2-by-2-inch lumber and covered, front and sides, with welded wire screen of 1- by 1.5-inch mesh. Bottom edges of the pens are securely anchored in the pond bottom by burying a 2-by-6-inch timber in the soil and nailing the frame to it. The back of the pens are walled up with concrete blocks set into the pond levee. An artificial nest made from a 10-gallon milk can or a 50-pound grease drum is placed on its side, near the center of the pen, in 24 to 26 inches of water, the nest is securely anchored with stakes and wire, and the bottom of the opening is placed flush with the pond bottom.

About April 15, the fish are sexed and a pair released in each pen. No gravel is placed in the container, as the male will remove it in his continual nest cleaning. The male stays near the female until she is ready to spawn—sometimes as long as a week will elapse. Eventually the female enters the nest and deposits a layer of eggs. The male then pushes her aside and fertilizes them. This process is repeated until the female is spent, after which the males drives the female from the nest and begins circulating the water and caring for the eggs. At this point, it is well to remove the female from the pen as she will continuously try to eat the eggs. All matings are not successful, and it is sometimes necessary to replace the female (if she refuses to lay eggs in a clean nest) or the male (if he refuses to clean the nest).

The incubation period is usually 9 to 10 days in May and 8 to 9 days in June. During incubation, the male should not be molested, since any disturbance may cause him to eat or move the eggs. After hatching the fry are carefully poured from the nest into a tub and transferred to board feeding troughs made from 1-by-12-inch pine boards 12 feet long. There is a continual flow of water through the troughs. Each trough is usually stocked with the contents of a single nest; ordinarily 10,000 to 20,000 fry. After transfer to troughs, the fry are not fed until the yolk sac is absorbed (approximately 4 days) and fed lightly for the following few days. Food used is a special preparation consisting mostly of milk powder, fish meal, meat and bone scraps and brewers yeast. Troughs should be cleaned of any extra food not eaten within two hours after feeding.

Fish are kept in the troughs at least nine days after which they are removed with a hand net and placed in a square tub for transfer to the culture pond. After tempering, the square tub is placed on its side, in water about 30 inches deep, facing away from the sun and is surrounded with a hardware cloth retainer to deter predators. Feeding is started immediately, and experience indicates that the longer the fry can be kept in the vicinity of the tub, the better the survival. The tub should be left in the pond about two weeks, and after its removal, feeding should be continued at the same location. There should be at least four feeding stations per surface acre of culture pond—the more the better for uniform growth. Culture ponds, which range in size from one to four acres, should be left dry as long as possible and filled immediately before receiving the fry to prevent development of predaceous insects. If air-breathing insects are present, the ponds are treated twice weekly with a mixture of one quart motor oil in five gallons of kerosene for a three acre pond.

Using the above, a successful hatch of 86 nests was obtained from 87 spawns in 1956. Approximately 500,000 fingerlings were reared for stocking.

Feeding brood stock is also important. They should be fed lightly with a small portion of cut feed, such as golden shiners and carp, in December, January and February. The amount of food given is increased about March 1, and by April the brood fish should be fed as much food as they will consume. This rate of feeding should continue until spawning. Fish weighing between 3 and 10 pounds, and varying between 3 and 6 years old, are most useful as brood stock.

COMMITTEE ON COMMERCIAL FISHERIES

R T. Whiteleather

During 1956, there were many bright spots in commercial fisheries, both from the standpoint of size of catch and new developments within individual fisheries. There were disappointments too in failure of some runs to live up to expectation. The net balance, however, was favorable for the year.

Canada

The Canadian catch was slightly over 2 billion pounds, valued at 104 million dollars to the fishermen, which was almost 13 percent more than the year before. The increase is attributed to larger production in the marine fisheries, since the fresh-water catch for the year was somewhat below that for 1955.

On the Pacific Coast, British Columbia fishermen took a total of 669 million pounds of fish and shellfish for which they received 36.6 million dollars, the second highest amount in the history of the fisheries. The herring fishery was unusually successful with landings for the year placed at 246,000 tons, the highest in the history of the fishery. This resulted in record production of herring meal and oil, with meal production at 45,000 tons, and herring oil production at 41 million pounds—10 million pounds more than ever produced previously.

The halibut fishery was a significant feature in the West Coast production in 1956. Landings amounted to 23.3 million pounds compared with 20 million pounds in the season before. The prices paid to the fishermen for halibut were the highest in history, which enhanced the total returns to the fishermen considerably in comparison with the 1955 season. Towards the end of the season, cold storage holdings of frozen halibut were high and considerable difficulty was experienced in disposing of the supply. Consequently, wholesale prices towards the end of the year failed to reflect the high prices paid for the fish.

The salmon fishery showed some downward trend with about 117 million pounds being landed, which was 17 million pounds less than in the previous season. The value of the catch, however, was up because of the strong tone of the market throughout the season. The lower catch of salmon was due, largely, to reduced landings of chum salmon. The failure of the chum salmon run to measure up to expectations was very disturbing, since heavy runs were anticipated. The summer run yielded only 10 million pounds and in the fall there were few areas that came up to normal yield. Fishermen and management officials have been somewhat puzzled by the unexpected decrease in the salmon abundance for the year.

Despite the disappointment in salmon production, the market value of all fishery products on the Pacific Coast of Canada in 1956 was fourth highest on record. Higher prices to both fishermen and processors combined to bring the market value up to this level.

In the Atlantic Provinces, the quantity of all fish landed was substantially larger than the year before. Landings of groundfish were up considerably. Particularly in the Maritime Provinces and Quebec, lobsters continued their position as a species of high value to the fishermen. In the Atlantic area, generally, the lobster catch continued to establish records in both volume and value. Landings during 1956 totalled over 51 million pounds, for which the fishermen were paid $17,800,000. A good share of the catch was sold in the shell and a substantial portion exported to the United States, as records indicate that nearly 22.5 million pounds of live lobsters were shipped across the border in 1956.

Apart from the statistical aspects of the fisheries, some notable developments affecting the commercial fisheries also warrant recording here. Lamprey research and control activities in the Great Lakes were again stressed in 1956. A new biological station of the Fisheries Research Board of Canada was established at London, Ontario, to concentrate mainly on Great Lakes problems.

New ocean perch fishing grounds were discovered north of the Flemish Cap with good catches from depths of 200 to 300 fathoms. In the Maritime Provinces there was a considerable spread in oyster disease along the mainland shore of the Gulf of St. Lawrence which reduced the oyster population badly.

The Canadian Government granted permission for the use of aureomycin and terromycin for preservation during the marketing process of fresh fish.

On the West Coast of Canada, far ranging studies were being carried out as part of the research by those countries under the International North Pacific Fisheries Commission to determine the distribution of American salmon stocks and to identify and distinguish between them and the Asiatic stocks.

The rapid growth of gas well drilling which started about five years ago is reported to be adversely affecting some fishery production in the Lake Erie area. Perhaps the most active problem on the Canadian West Coast has been the question of compatibility of power dam construction and salmon production. Fishery management experts gave careful study to the problems of water utilization for power purposes at the possible expense of the salmon fishery.

UNITED STATES

The total catch of fishery products in the United States and Alaska has been maintained at a relatively high level during recent years, but the catch of 5.2 billion pounds in 1956 tops all previous records. Preliminary figures also show a high value to the fishermen totalling 354 million dollars.

Some definite changes in the composition of the catch have been taking place. The proportion of the catch for food use has declined sharply. During the period from 1946 to 1950, the average catch of food fish was 3.2 billion pounds. For the five ensuing years, this average dropped to 2.8 billion pounds, or a decline of 400 million pounds. The total catch has been maintained by a sharp increase in the volume of fish taken for manufacture into meal and oil, or for other industrial purposes and bait.

In addition to that part of the catch used directly for industrial purposes, about 650 million pounds of waste derived from filleting, canning, or otherwise preparing fish for market, was utilized in the production of fish meal and oil. This means that nearly 60 percent of the United States catch ultimately reached the market as industrial products.

While the domestic catch of food fish has declined, consumption has been maintained at a relatively constant level through acceleration in the amount of imports of edible fishery products. In the period immediately after World War II, imports accounted for about 20 percent of the supply. In recent years this ratio has risen to about 35 percent. This has tended to hold down production incentive in the domestic fisheries and has created severe maladjustment in several important segments of the United States fisheries. The New England groundfish industry particularly has felt this impact and there has been a continuous reduction in the number of trawlers, the principal producing units. The California tuna fishery has likewise been affected, and in the years since World War II the number of large tuna clippers has declined from 214 to about 155

Changes in retail preparation of fishery products to meet consumer desire are influencing certain fisheries. Because of merchandizing preferences for products which require little or no preparation in the home, the market for much of the whole and dressed fish formerly sold in large quantities is dwindling with resultant effect on production of those species.

Wide fluctuations have occurred in the production of various fisheries during the last quarter century — some fisheries have almost disappeared while new ones have been developed. This brought about several important changes in 1956 with regard to the position of individual species within the total catch figure. The once great California sardine fishery again failed to produce significantly in 1956. The 66 million pounds taken was a sharp reduction compared to the 146 million pounds in the previous year, and, of course, only a fragment, or about 4 percent, of the 1936 record catch of 1.5 billion pounds.

Conversely, on the Atlantic Coast the menhaden industry took a record quantity with the catch exceeding 2 billion pounds in 1956. This was nearly 40 percent of the total volume of fish and shellfish caught by United States and Alaskan fishermen during the year. Principal factors which have contributed to the large catches of menhaden in recent years are (1) an extremely abundant year-class, which has dominated the catch for some years; (2) expansion of the fishery to the Gulf of Mexico; and (3) the increased use of aircraft to locate schools of menhaden.

The South Atlantic and Gulf States catch of shrimp which is the number one fishery in value, amounted to approximately 220 million pounds, which was about 10 percent below 1955.

The salmon catch increased to about 311 million pounds from the low figure of 290 million in 1955. Production in Alaska was up sharply largely because of heavier runs of red salmon. The Pacific Coast salmon production was off mainly because of the normal absence of pink salmon in the Puget Sound area in even numbered years.

The California mackerel fishery was up substantially in 1956. The failure of the sardine fishery resulted in diversion of vessels to mackerel fishing. Mackerel were abundant and much larger catches could have been made had there been a greater demand for the canned product. The catch of jack mackerel amounted to 77 million pounds, more than double that of the previous year, and the catch of Pacific mackerel totalled 48 million pounds, again more than twice that of the previous year.

Pacific Coast tuna landings amounted to 327 million pounds which was considerably above the low catch of 269 million pounds taken the previous year.

Landings in the New England groundfish industry also showed a small increase, principally because of the larger catches of haddock. Imports of groundfish and ocean perch fillets in 1956 reached a record of 135 million pounds which is 56 percent of the total domestic supply.

The ocean shrimp fishery off California has continued to expand and now ranks as one of the important fisheries of that State. As a result of exploration of new resources by the Federal Government a shrimp fishery has been developed off the State of Washington where sizeable catches are being made for canning. Off the Coast of Florida, commercial production of the new deep water red shrimp was begun, and in the Gulf of Mexico fishermen began to tap a formerly unknown tuna resource. Further, exploration in the North Atlantic resulted in rather surprising catches of albacore and yellowfin tuna, which may indicate some commercial possibilities for these species in that area.

The increase in the use of aircraft to locate schools of fish seems significant. Air spotting has become a common procedure in the menhaden fishery along the Atlantic and Gulf Coast and in the locating of certain sardine-like fishes on the Florida West Coast. Many California tuna clippers are carrying small planes for scouting purposes on trips to Central and South American waters.

Unique action was taken to halt the recent development of off-shore salmon fishing with nets in the North Pacific because of the adverse effect on management of this large fishery in general. Action was taken through interstate, international and inter-agency cooperation at the request of the fishing industry. This clearly represents the effectiveness of group action in meeting with expediency the need for regulations in conservation of a fishery resource. United States fisheries scientists joined in the extensive North Pacific salmon investigations in carrying out segments of that program to identify and distinguish American and Asiatic salmon stocks under the International Commission mentioned earlier in this report.

There has been increasing evidence of closure of certain fisheries to commercial activities in recent years. One of the latest actions is that of the California Legislature passing a bill to prohibit all salmon gillnet fishing in the Sacramento River after the 1957 season ending on September 26. Thus ends a long chapter in commercial fishing history that started with the establishment of the first Pacific salmon cannery, nearly 90 years ago.

As Chairman of the Commercial Fisheries Committee I am indebted to members of the Committee for their efforts in furnishing much of the information in this report. Without their assistance, this summary of North American fishery developments would have been much more time consuming and difficult.

COMMITTEE ON WATER POLLUTION

Peter Doudoroff

Early in the year 1955, the Committee on Water Pollution, having become a standing committee, undertook a continuing survey of water pollution research and abatement activities throughout the United States and Canada. Our plan has been to request information once in three years from each regulatory (pollution control) agency and also from every organization believed to be engaged in biological research having to do with the effects of water pollutants upon aquatic life and fisheries. By covering about one-third of the states and provinces every year (each every third year in rotation), we have hoped to be able to produce and maintain a fairly complete, up-to-date, and useful record of activity and progress in our field of interest, for the information of Society members.

The first three-year phase or cycle of the survey having been completed and our accomplishments reviewed, it must be admitted that we are still far from our goal of nearly complete coverage of the regulatory and research organizations from which information was to be obtained. There are two major reasons for the incompleteness of the available data and of our inventory of research projects. One is the failure of a number of recipients of our questionnaires to complete these report forms and to return them to committee members. Some of those failing to reply to our inquiries doubtless have not been actually engaged in pertinent activities, and therefore considered replies to be unnecessary. However, a number of organizations which are known to be still active, or to have been active very recently, in our field of interest also failed to submit completed questionnaires.

Another reason for the incomplete coverage is the to some extent unavoidable failure of committee members to send appropriate questionnaires to some of the regulatory agencies and research organizations or investigators who should have received them. While in some instances failures to make the necessary inquiries may have been due to negligence, mostly the oversights are doubtless ascribable merely to lack of information, on the part of individual committee members, concerning the activities and functions of the overlooked organizations. Communication among fishery biologists and others interested in water pollution problems has been quite inadequate in the past, so that these biologists too often have been unaware of important pertinent work in progress not only in distant places, but even in their own and neighboring states or provinces. The large variety of organizations engaged in these activities and of publications in which results are reported may be largely responsible. The work program of the Water Pollution Committee has been designed partly to overcome the difficulty of communication by informing interested biologists about important new developments and thus promoting better exchange of information.

Much more complete information than that which is now available doubtless can be assembled by the committee in the next three years. Important omissions in the original inventory of regulatory agencies and research organizations now can be reaily called to the attention of the responsible committee members by other members having pertinent information. Informed persons might be profitably invited to review critically the assembled data and to point out omissions, and it is to be hoped that others will volunteer such help. Helpful information and suggestions to be found in returned questionnaires could be utilized more fully than they have been heretofore, in the limited time available. The questionnaires doubtless can be improved and perhaps can be profitably simplified, and increasingly effective letters of transmittal and follow-up inquiry devised, in the hope of obtaining a better response to the committee's requests. Improvements of the organization and direction of the collection of desired data, based on past experience, undoubtedly can be achieved. The initial work already has brought together much valuable information not to be readily found elsewhere, so that desirability of continuation of the survey in accordance with the original plan seems to be indicated.

It is impossible adequately to present in this brief report the committee's findings of the past year. As in the past, the new information collected is to be summarized in a mimeographed supplementary report which will be available to all interested members of the Society. Unfortunately, because of late receipt of the information to be included, and for other reasons, this third supplementary summary report could not be completed and reproduced in time for distribution at the 1957 annual meeting of the Society. Copies will be sent as soon as possible to all members requesting them, and remaining copies may be distributed to interested members in attendance at the next annual meeting. In the present report only a few observations and facts of general interest derived from the newly assembled and classified data can be mentioned.

There has been recently considerable interest in legislative activity in the field of water pollution control. Of the thirteen states and two provinces from which new information was received in 1957 (reports from 20 regulatory agencies), eight states, namely, Georgia, Montana, Nebraska, Maine, Nevada, Idaho, North Carolina, and Wisconsin, and two provinces, New Brunswick and Ontario, were said to have had some important new pollution control legislation passed during the past three years; and the legislature of Florida also was said to have been considering such legislation. It appears that both of the provinces, the first three or four of the states named, and also Florida, may have very recently acquired their first comprehensive and effective water pollution control laws giving broad regulatory powers to the responsible agencies. A number of other states evidently still lack such laws. A new bill has very recently (in 1957) eliminated a section of the old water pollution control law of Nevada which exempted "mills or works for the reduction of ores" from the provisions of the law prohibiting pollution harmful to fish life. The Federal Water Pollution Control Act has been extended and strengthened considerably by the Water Pollution Control Act Amendments of 1956 (Public Law 660—84th Congress). Several state pollution control agencies have reported that certain provisions of this act, such as those authorizing federal grants to states, municipalities and certain other agencies to assist them in the development of water pollution control programs and the construction of sewage treatment works, have been very helpful to them in discharging their responsibilities. It is too early, of course, to evaluate the over-all influence or efficacy of all the new legislation considered above.

More increases (8) than decreases or shortages (2) of personnel assigned to pollution control work have been reported by the regulatory agencies whose reports are considered here. However, only a few have reported rather large recent increases of personnel and facilities for this work and half of the agencies reported no significant change.

Regulatory agencies of the states of Wyoming, Wisconsin, Rhode Island, North Carolina, Georgia, and Louisiana have reported substantial progress in pollution abatement, including correction of some previously existing pollutional conditions, during the past three years. Several others have reported the adoption of important new waste control regulations for the protection of fish life, classification of additional waters as waters suitable for fish, prevention of pollution from new sources, and other accomplishments. The South Carolina Water Pollution Control Authority reports considerable difficulty in justifying the requirement of large capital outlays for waste treatment needed for the protection of fish and fisheries only, but some progress also is reported. The Wisconsin Committee on Water

Pollution reports that irrigation disposal methods for cannery wastes, whereby these wastes can be kept out of surface waters entirely, have been highly successful.

Additional reports of current and recent research in aquatic biology relating to water pollution and its effects on fish and fisheries which have been received again suggest serious inadequacy of the total research effort in this field. Considerable emphasis on studies of the toxicity of industrial effluents, waste components, and other pollutants to aquatic life is indicated, eight of thirteen organizations reporting any biological research having been involved in studies of this nature. Attention has been given also to the effects of deposition of silt and reduced dissolved oxygen concentration on the developing eggs of salmonid fishes in spawning gravels, three reporting organizations having been engaged in pertinent studies. Studies of fish flavor and of the biology of aquatic insects in relation to water pollution also have been reported. Limnological and oceanographic field studies or surveys having to do with specific pollution problems have been carried on by at least five of the organizations. Although reported as research, some of these investigations incidental to the enforcement of pollution control laws perhaps should not be so classed. There is evident need for more basic research, without which pollution control measures and water quality standards intended for the protection of fisheries cannot be well founded. Such studies should be more intensively prosecuted or adequately supported by those who need the information to be derived therefrom.

The Water Pollution Committee wishes again to acknowledge with thanks the valuable help of all who have taken the trouble to complete and return the questionnaires used in conducting our survey. Their cooperation is deeply appreciated.

COMMITTEE ON FINANCE

Edward Schneberger

The Auditing Committee for 1956 called attention to two specific financial problems and recommended that a special committee be appointed to study these problems and to report to the 1957 meeting of the Society. The problems outlined by the Auditing Committee are as follows:

1. Payment for clerical and stenographic services for the Secretary-Treasurer.
2. Employment of editorial services.

It was pointed out that the Secretary-Treasurer has a heavy load of correspondence, bookkeeping and other stenographic and clerical chores. These services have been provided by the agency employing the Secretary-

Treasurer. While the Society is extremely grateful for this cooperation, it is unfair and unreasonable to expect that these services in such volume continually be donated to the Society. Therefore, the Auditing Committee felt that the Society should make plans to pay its own way in this regard.

The second problem deals with editorial services and the publication of the annual Transactions. It is recognized that the long delay in the publication of the Transactions after each annual meeting has many detrimental effects. New members wonder what they get for their dues and many good fish papers are submitted to other journals for publication. The Society, in recognition of the editorial problems, last year made $1,000.00 available to aid in preparation of the 1956-57 volume for publication. The current report of the Editor will show that this was a wise expenditure.

The function of the Finance Committee is, therefore, to determine the amount of additional funds that will be needed and to suggest ways and means of providing such funds.

1. Amount of Additional Funds Needed

Since the Society has no previous experience in employment of these services, the Committee submits the following figures as "guess estimates". It is believed best to initiate any new procedure on a modest budget and expand as future experience dictates. With the exception of the allocation made last year, there is no measure of the costs of editorial services. Therefore, the Committee merely doubled the amount already allocated for this function. The amount for secretarial services is based on estimates provided by the Secretary-Treasurer.

Editorial Assistance	$ 2,000.00
Secretarial Services	2,500.00
Contingencies and Incidentals	500.00
	$ 5,000.00

The budget of $5,000.00 is purposely a modest and conservative estimate. The cost of stenographic services, for example, will vary with the amount of service needed, the prevailing wage rate and the geographic region where the work is done. It is anticipated that the work load will increase rather than decrease and, therefore, these services can be expected to be more costly in the future.

In regard to the editorial services, it must be recognized that to many of the professional members of the Society, the chief value of the Society to its members lies in the Transactions as a ready source to literature references to fisheries and a place to publish their papers. However, the Society cannot afford to allow the practice of tardy publication to continue.

Neither can the Society permit any sacrifice in quality of the publication. Prospective authors must be assured that not only will their papers be published within a reasonable period, but also that acceptance of their paper for publication in the Transactions is an indication that the paper has met reasonably high standards. Therefore, the investment by the Society in editorial services should pay rewarding dividends by attracting and holding members.

It is conceivable that the additional funds needed could easily grow to about $8,000.00. Without going into detailed accounting it is also conceivable that the normal expenses of the Society will increase as various costs continue to rise. It is not unreasonable to expect that the Society would eventually need an annual income of $18,000 to $20,000. Certainly, any plan of payment for secretarial services and editorial assistance adopted will require additional income.

2. MEANS OF INCREASING REVENUE

Following are suggested ways by which the annual income might be increased. Each will be discussed.

(a) Increase active membership dues.
(b) Recruit more members.
(c) Solicit more sustaining members.
(d) Solicit more patrons.
(e) Sell advertising space in TRANSACTIONS.

(a) INCREASE IN MEMBERSHIP DUES

At present the dues of the active members constitute the principal source of income. The annual dues were increased from $4.50 to $5.00 within the past year. It is doubted that further increase in active membership dues will provide additional income at this time because many members might drop out because of lack of service from the Society. It is also pointed out that there are many non-professional people that are members. An increase in dues might cause these members to drop out.

It is possible that eventually there might be two classes of active memberships—one for the professional fishery worker at $7.50 to $10.00 per year and one for the non-professional or layman and including students for the present $5.00 rate. It would be necessary to define the non-professional very accurately in order to avoid the embarrassing situation of having the entire active member list classified as non-professional. There are many other problems that must be solved before such a plan is adopted. For example, would a non-professional be permitted to hold office and serve on committees?

(b) RECRUIT MORE ACTIVE MEMBERS

At present there are slightly less than 2,000 active members, and as stated previously this is the primary source of income. If, at the present dues, the active membership could be doubled, the annual income would be increased $8,000-$10,000. Can a goal of 4,000 active members be achieved? A vigorous and continual drive for active members would be necessary.

(c) SOLICIT MORE SUSTAINING MEMBERS

The fee for a sustaining member presently is $10.00 per year. It has been suggested that this fee be raised to possibly $25.00 and a membership drive initiated to obtain members. The possibilities of this move are unknown. There are, however, many sources of sustaining members such as various clubs, private fish hatchery operators, minnow dealers, sporting goods store operators, manufacturers, etc.

(d) SOLICIT MORE PATRON MEMBERS

The requirement for a patron is a single contribution of $250 or more. Just how far this may be utilized is unknown.

(e) SALE OF ADVERTISING SPACE IN THE TRANSACTIONS

The sale of advertising space in the Transactions was suggested by the Executive Committee at their regular meeting in Washington, D.C. last winter. Therefore, the Chairman contacted the Arthur Towell Advertising Agency of Madison, Wisconsin, for a study of this possibility. A study of publications with limited distribution shows that the rate varies from about $200 to $600 per page. The agency advises that if the American Fisheries Society is to sell advertising space, the rate should be about $200 per page and $110 per half page with no allowance for advertising agency commission.

The report further points out that the big problem would come in trying to find someone to sell the space. It is also indicated that the Society's best opportunity to sell space might be through a special committee who have friends in business and can persuade possible prospects.

It is estimated that 10 pages of advertising might net the Society about $1,500 profit. It is believed this would be a poor means of increasing revenue, and if it is necessary to persuade prospects it would be more dignified to sell them memberships as patrons.

RECOMMENDATIONS

The Committee on Finance respectfully recommends to the members of the AMERICAN FISHERIES SOCIETY:

1. That for the fiscal year 1957-1958 the Society approve the recommended budget of $5,000.00 as follows:

Editorial assistance	$ 2,000.00
Secretarial service for Secretary-Treasurer	2,500.00
Incidentals	500.00

2. That this cost be charged to the general fund but in the event of a deficiency in the general fund the Secretary-Treasurer be authorized to transfer a sum sufficient from the permanent fund to cover such deficiency.

3. That the duties and functions of the Auditing Committee be expanded to include an annual review of the financial status of the Society and the Auditing Committee be authorized to present plans designed to increase revenue.

4. That advertising not be considered as a means of additional revenue.

BUSINESS MEETING AND REPORTS OF SESSIONAL COMMITTEES

The Business Meeting for hearing reports of Sessional Committees and election of officers convened in the New Frontier Hotel, Friday, September 13, 1957, at 3:00 p.m. President Clarence F. Pautzke presided.

President Pautzke called the chairmen of the Sessional Committees, Harry Cornell, Hjalmar O. Swenson, Fred Thompson, and Gerald P. Cooper to the rostrum to give their reports. Mr. Cornell presented the report and recommendations of the Time and Place Committee and moved its adoption. Seconded by Mr. Anderson of Ohio; put to a vote and carried unanimously. Mr. Cornell then pointed out that the committee had received two invitations for the meeting place of the 1960 meeting but had deemed it inadvisable to select a meeting place more than two years in advance. Mr. Seth Gordon, Chairman of Time and Place Committee of the International Association was asked to comment and stated "I think it would be a mistake, personally, to commit the meeting places beyond two years, but that matter could well be referred to the Executive Committees by special motion, asking them to give some though to the problems for the guidance of the Time and Place Committees next year." Mr. Cornell pointed out that the American Fisheries Society could effect such a rule only by amendment of the by-laws. After some discussion, Mr. Cornell made a motion that "the by-law pertaining to the Time and Place Committee be revised to state that this committee should not recommend establishment of times and places of meetings more than two years in advance." The motion was seconded by Mr. Roach of Ohio. After some discussion by Dr. Schneberger of Wisconsin and Dr. Hazzard of Pennsylvania, it was put to a vote and carried by the necessary two-thirds majority (48 for; 14 against).

Hialmar O. Swenson presented the report of the Auditing Committee, commending Everett Speaker for a fine job done during his term of office as Secretary-Treasurer and moved adoption of the report. Seconded by Dr. Carlander of Iowa. After some discussion, the motion was put to a vote and report of the Auditing Committee unanimously adopted. President Pautzke then called on Dr. Edward Schneberger of Wisconsin to present the report of the Finance Committee. Dr. Scnneberger pointed out that copies of the report of the Finance Committee had been available for study by members of the Society present at the meeting. He moved that Items 1 and 2 of this report be adopted. Seconded by Mr. Greene of Wyoming. President Pautzke put the motion and explained that the two items included in the motion were: (1) approval of the proposed $5,000.00 budget for 1957-58 and (2) approval for paying such budgeted costs from the general fund with the Secretary-Treasurer being authorized to transfer assets from the permanent fund to the general fund in amounts sufficient to cover any deficits. Motion passed unanimously. Dr. Schneberger then discussed Item 3 of the report of the Finance Committee and moved that the "duties and functions of Auditing Committee be expanded to include an annual review of the financial status of the Society; and (that) the Auditing Committee be authorized to present plans designed to increase revenue." Seconded by Seth Gordon of California. After discussion in which Secretary Speaker expressed the opinion that passage of the motion would not necessitate change of the by-laws, the motion was put to vote and carried unanimously. Dr. Schneberger then moved the adoption of Item 4 of the Finance Committee Report "that advertising (in the TRANSACTIONS) not be considered as a means of additional revenue (to the Society)". Seconded by Dr. Donaldson of Washington. After considerable discussion and expression of differences of opinion, Dr. Moyle of Minnesota moved that the motion be tabled. Seconded by Mr. Calhoun of California and passed unanimously.

President Pautzke then called on Mr. Fred Thompson of New Mexico for the report of the Resolutions Committee. Mr. Thompson presented 12 resolutions and withheld for further discussion any to which there were objections during the initial presentation. He moved the simultaneous adoption of seven resolutions[1] to which no objections had been expressed. The motion was seconded by Mr. Seaman of Virginia and passed unanimously. Two other resolutions[2], one concerned with use of water and one concerned with maintenance of fish structures associated with federal dams were passed unanimously after some discussion and rewording. The first was seconded by Mr. Shapovalov of California and the second by Mr. Gordon of California and Dr. Hazzard of Pennsylvania. In their original form the resolution concerning pesticides and an amendment to it were lost after their adoption was moved by Mr. Henderson of Ohio and seconded by Dr. Moyle of Minnesota. Later in the meeting the adoption of another resolution on the same subject[3] was moved by Mr. Henderson of Ohio, seconded by Mr. Whiteleather of Washington, D. C., and passed unanimously. A resolution concerning the proposed Nez Perce dam and a resolution pertaining to relationship of highway to impoundment construction were both lost for want of seconds.

COMMITTEE ON TIME AND PLACE

J. H. Cornell

The Time and Place Committees of the International Association of Game, Fish and Conservation Commissioners and of the American Fisheries Society met in joint session and considered firm invitations from four different states which offered their hospitality to the two organizations for their 1959 meetings. In addition, it is noteworthy that two states requested consideration for the 1960 meetings.

The Committees considered the propriety of making meeting commitments three years in advance instead of two. It was recognized that some large organizations must follow this practice in order to have adequate hotel facilities guaranteed. Your Committees decided that the combined membership of the two organizations is such that planning beyond two years is not essential.

Another consideration of your Committees, which we believe merits your attention, is the fact that long advance commitments may destroy some of the usefulness of our meetings in promoting the cause of sound progress in the conservation field. Situations have arisen in the past, and may well arise in the future, where it was extremely desirable to select a meeting place on the basis of the benefits which might accrue to a given area. The presence of the combined meetings in a critical location can materially help to strengthen and stabilize programs which deserve the support of these organizations. Because situations needing such support can develop on short notice, the Committees believe it to be desirable to limit definite meeting commitments to a maximum of two years.

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[1] Resolutions No. 2, 4, 5, 6, 7, 8 and 10 of the Report of the Resolutions Commitee.
[2] Resolutions No. 1 and 3 of the Report of the Resolutions Committee.
[3] Resolution No. 9 of the Report of the Resolutions Commitee.

The constitutions and by-laws of the two organizations set no limit on the number of years for which meeting places may be recommended by their Time and Place Committees. We suggest that both the International Association and the American Fisheries Society consider the pros and cons of this problem at appropriate future meetings. The desirability of doing so is indicated by the requests we received for a commitment for the 1960 meeting place.

As was determined in 1956, the joint committee reminds you that the 1958 meeting will be held at the Benjamin Franklin Hotel in Philadelphia, Pennsylvania, during the week of September seventh. It being an even-numbered year, the custom will be observed of holding the meeting of the American Fisheries Society on Monday and Tuesday, and that of the International Association on Thursday and Friday.

In preparing their recommendation for the 1959 meeting, your committees carefully considered the locations of meeting places during the past quarter of a century, and also gave the thought to the benefits which might accrue to the conservation programs in the several geographic regions. The Committees jointly recommend that, it being an odd-numbered year, the International Association hold its meeting on Monday and Tuesday, September 14 and 15, and that the American Fisheries Society hold its meeting on Thursday and Friday, September 17 and 18, with Wednesday being devoted to such activities as the two program committees may consider desirable.

It is recommended by your Time and Place Committees that the 1959 meetings of the two organizations be held at Clearwater, Florida.

AUDITING COMMITTEE

Hjalmar O. Swenson

The Auditing Committee has examined the accounts of the Society for the fiscal year 1956-1957 and found them to be correct. The Committee also examined the report of Mr. R. W. Paton of the State Auditor's Office, State of Iowa, dated September 6, 1957, covering the entire period served by Mr. E. B. Speaker, the outgoing Secretary-Treasurer, and found the accounts of the Society to be in good order to be turned over, together with all bonds, receipts and other records, including receipts to August 31, 1957, to the incoming Secretary-Treasurer. The Committee wishes to commend the Secretary-Treasurer and those who aided him for the excellent handling of the Society's records and accounts.

NOMINATING COMMITTEE

GERALD P. COOPER

Your Nominating Committee consists of five members: Willis King of Georgia who is Chairman; Richard Croker of California; Cliff Millenback of Washington; John Kask of Ontario; and myself.

The committee agreed that two names would be presented for the Office of Second Vice-President, also that these two men should represent the same general professional background or type of employment. Each committee member proposed a list of candidates for the several offices and the lists were combined into one. This combined list was re-circulated among the Committee members and final selection made from it by voting of the Committee members. It is perfectly proper to present additional nominations from the floor both for officers and committee members.

We are recommending one name for the offices of President, Vice-President, Secretary-Treasurer and Librarian and two names for the office of Second Vice-President as follows:

President—H. S. Swingle of Alabama
First Vice-President—W. Mason Lawrence of New York
Secretary-Treasurer—E. A. Seaman of Washington, D. C.
Librarian—Howard A. Tanner of Colorado
Second Vice-President—A. V. Tunison of Washington, D. C.
James W. Moffett of Michigan

For each of the six standing committees, we are offering a single slate of nominees. According to our by-laws, five of these committees are to consist of seven members and one (National-State Relations) consists of five members. The following names are presented in nomination:

COMMITTEE ON INTERNATIONAL RELATIONS

Milton C. James, *Chairman,* Oregon
W. C. Beckman, Syria
Robert G. McMynn, British Columbia
Leslie W. Scattergood, Maine
Norman S. Baldwin, Ontario
William A. Dill, Italy
Garth Murphy, Hawaii

COMMITTEE ON NATIONAL-STATE RELATIONS

Alexander J. Calhoun, *Chairman,* California
Paul H. Eschmeyer, Michigan

A. F. C. Greene, Wyoming
Edward Whitesel, Alaska
Gordon E. Hall, Florida

COMMITTEE ON WATER POLLUTION

Clarence M. Tarzwell, *Chairman,* Ohio
Max Katz, Oregon
John L. Hart, New Brunswick
Eugene W. Surber, Georgia
George E. Burdick, New York
Gordon Gunter, Mississippi
Erling J. Ordal, Washington

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

F. E. J. Fry, *Chairman,* Ontario
Stanislas F. Snieszko, West Virginia
Peter A. Larkin, British Columbia
W. Harry Everhart, Maine
I. B. Byrd, Alabama
Joseph H. Wales, California
C. J. D. Brown, Montana

COMMITTEE ON COMMERCIAL FISHERIES

Donald L. McKernan, *Chairman,* Washington, D. C.
Stanford H. Smith, Michigan
E. S. Marvich, Alaska
Donald E. Kauffman, Washington
Harold F. Cary, California
Percy Viosca, Jr., Louisiana
Willard A. Van Engel, Virginia

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey, *Chairman,* Michigan
Ernest A. Lachner, Washington, D. C.
Edward C. Raney, New York
William B. Scott, Ontario
Loren P. Woods, Illinois
C. Richard Robins, Florida
Phil M. Roedel, California

CONCLUDING BUSINESS

The report of the Nominating Committee was then presented. President Pautzke then called for any additional nominations from the floor for members of Standing Committees. (There were none). Dr. Donaldson of Washington moved the nominations presented by the Nominating Committee be accepted. Seconded by Mr. Campbell of Oregon, and passed unanimously. The President then pointed out that only one name had been submitted in nomination for each of the offices of President, First Vice-President, Secretary-Treasurer and Librarian and called for any additional nominations from the floor (There were none). Mr. Fred Thompson moved that the nominations stand as presented by the Nominating Committee. Seconded by Mr. Wagner of Washington. There being no discussion, the question was put to a vote and passed unanimously. The office of Second Vice-President was then considered, two nominees having been proposed by the Nominating Committee. Nominations from the floor were called for (There were none). Ballots were distributed and a vote taken with Mr. Campbell of Oregon and Dr. McKay of Ontario acting as tellers. After the votes were counted, President Pautzke announced the results as 21 votes for Dr. Tunison and 42 votes for Dr. Moffett and declared Dr. Moffett elected Second Vice President. [Applause.]

President Pautzke: I would now like our most southerly member in attendance, Clare Idyll of Florida, and the most northern member, H. H. McKay of Ontario, to escort the new President to the podium. [President-elect Homer S. Swingle is escorted to the rostrum with rising applause from the audience.]

President Pautzke: Your new President has been a real work-horse for the Society this past year and it has been a real pleasure and a great help to have had Dr. Swingle as my First Vice-President. I am also grateful for the privilege of having worked with Mr. Speaker. During my term of office he has frequently showed me the right way to go. And in the background helping to keep the Society going has been Mr. Speaker's Secretary, Mrs. Thayne Wright. Will she please stand? (Applause for Mrs. Wright). Is there any additional business?

Mr. Dwyer (California): Mr. Chairman, I wish to move that the Society's Editor be authorized to correct grammar and construction of the resolutions that the organization has adopted, remaining within the intent of the resolution.

(Motion seconded by Dr. Raymond Johnson and after some discussion put to a vote by show of hands. (Carried 27 to 20).

President Pautzke: Doctor Swingle it is now my pleasure and privilege to turn the chair over to you as the new President of the American Fisheries Society. To the members of the Society may I express my appreciation; I have sincerely enjoyed working with you as your President during the past year. [Rising applause]

President Swingle: My first act as President is to thank Mr. Pautzke on behalf of the Society for his diligent and efficient work during his term of office and to express our appreciation for the spirit he brings to these meetings; an informality that has allowed all of us to relax a bit and have a better time while getting the work done. Next, I would like the First Vice-President, Second Vice-President, Secretary-Treasurer, and Librarian—and also the retiring Secretary-Treasurer—to be seated on the rostrum with me.

I will not say much about what we are going to do, but it will be the best we can and in whatever we do we will need the help of all the members.

We will now go on with the remaining business of this meeting. There is one thing the President is supposed to do promptly and that is to appoint an Editor. Dr. Moyle has consented to continue as Editor for the coming year. He and the other members of the Editorial Board have indeed done a commendable job this past year.

A word of appreciation for the Associate Editors, who review and referee those papers submitted for publication in the Transactions, is certainly in order. They do a tremendous amount of work for us and usually get little recognition for it.

In concurrence with your wishes, as expressed at this meeting, I will appoint an Auditing Committee at this time since under the change in the by-laws made at this meeting it now is charged with the additional job of planning the Society's finances. I am appointing Edward Schneberger as chairman and Richard Stroud and Raymond Johnson as committee members.

There is another item of importance that should be acted upon. Since the Society has been assembled at Las Vegas several additional names have been proposed for membership. Mr. Speaker, would you please present them? (Mr. Speaker presents four names for membership and moves they be accepted into the Society; the motion is seconded by Dr. Carlander and passed unanimously.)

MR. SETH GORDON: Mr. President, may I commend all of those in attendance at this meeting for their sincerity of purpose and good attendance at the sessions—despite many outside distractions. One of our friends and a former President and Secretary-Treasurer, George Sprecher of Wisconsin, is not here this year, and I understand, is quite ill, I would suggest that the Society wish him Godspeed in his recovery.

PRESIDENT SWINGLE: I am sure this does not require formal action, our Secretary will take care of it. Is there any other new business?

MR. JOHN FUNK (Missouri): Mr. President I move that a committee be appointed to study the effects of increased use of pesticides on fish and wildlife.

(There was considerable discussion of this motion. President Single suggested that it be referred to the new Resolutions Committee. With this Mr. Funk concurred. Mr. Stroud pointed out that the Metcalf Bill was now before Congress provides finances for investigation of effects of pesticides by the U. S. Fish and Wildlife Service and stated that, in his opinion, all that was necessary was a statement indicating support of the Society for the Bill. Dr. Johnson (Minnesota) suggested that this problem be referred to the Pollution Committee. The motion that the matter be referred to the new Resolutions Committee was placed before the meeting by the President and passed by a 27 to 7 vote).

PRESIDENT SWINGLE: A motion for adjournment is now in order.

DR. SCHNEBERGER, Wisconsin: I move we adjourn.

(Seconded by Dr. Donaldson of Washington and passed unanimously).

The 87th Annual Meeting of the American Fisheries Society at the New Frontier Hotel, Las Vegas, Nevada, adjourned at 5:40 p. m. September 13, 1957.

Appendices

CONSTITUTION AND BY-LAWS OF THE AMERICAN FISHERIES SOCIETY

(Revised 1957)

ARTICLE I

Name, Objectives and Purposes

1. The name of the organization shall be the American Fisheries Society, hereinafter referred to as the Society.

2. The objectives and purposes of the Society shall be:

(a) To promote the conservation, development and wise utilization of the fisheries, both recreational and commercial.

(b) To promote and advance the development and application of all branches of fishery science and practice, including aquatic biology, engineering, economics, fish culture, limnology, oceanography and technology.

(c) To gather and disseminate technical and other information on fishes, fishing, fisheries, and all phases of fishery science and practice.

(d) To hold meetings for the presentation, exchange, and discussion of information, findings and experience on all subjects and techniques related to fishes, fishing, fisheries, and all phases of fishery science and practice.

(e) By such other means as may be appropriate, to unite and encourage those interested in fishes, fishing, fisheries, and all other phases of fishery science and practice.

ARTICLE II

Membership and Election of Members

1. The membership of the Society shall be of the following classes:

(a) *Active Member:* any person interested in the Society and in the furtherance of its purposes and objectives is eligible for the election as an Active Member.

(b) *Life Member:* Any duly-elected active member, upon payment of the fee for life membership as specified in the By-laws, may retain his status as an active member throughout the remainder of his life and shall be exempt from any further payment of dues.

(c) *Sustaining Member:* Individuals, any sporting or fishing club, any society, corporation or other organization is eligible for election as a sustaining member.

(d) *Library Member:* Any technical, public, private, or other library may become a library member.

(e) *Official* Member: Any Federal, State, Provincial, or Territorial department or agency of the United States of America, Government of Canada, United Mexican States, or any other American Republic is eligible for election as an official member.

(f) *Patron:* Any person, society, club, firm, corporation, or other organization is eligible to become a patron.

(g) *Honorary Member:* Honorary members shall be of two classes, *ex officio* and *distinguished service.* The President of the United States of America, the Governor-General of the Government of Canada, the President of the United Mexican States, the Governors of the States and Territories of the United States of America, the Lieutenant-Governors of the Provinces of Canada, the Secretary of the Interior of the United States of America, the Minister of Fisheries of Canada, and the Secretary of the Navy of Mexico shall be Honorary Members *ex officio.* Any other person of note, by reason of his professional or other attainments, outstanding service to the Society, or his official position, shall be eligible for election as a *distinguished service* honorary member.

2. Nominations for active membership, sustaining membership, library membership, official membership, and patron shall be submitted to the Secretary-Treasurer with the endorsement of at least one active member of the Society. Except as provided in paragraph 3, such nominations shall be presented to the members present at any regular or special meeting and shall be considered elected if they receive an affirmative vote of a majority of the members present at such meeting. Nominations for honorary membership shall be submitted with the endorsement of at least ten active members of the Society in good standing, and the unanimous vote of all members present at any regular or special meeting shall be required for election.

3. The Executive Committee, established pursuant to Article III, is authorized to consider and vote upon nominations for all classes of membership, except nominations for honorary membership, during the intervals between meetings. When so authorized by the Executive Committee, the President of the Society and the Secretary-Treasurer, acting jointly, may pass upon such nominations during the said intervals.

4. The names of elected members shall not be added to the membership rolls of the Society until they have paid such dues, fees or assessments for a period of at least one year as are enumerated in the By-laws adopted pursuant to Article V.

5. As used in this Constitution, and in the By-laws adopted pursuant to Article V, the term member "in good standing" means any active member, sustaining member, library member, or official member, whose dues are not more than one year in arrears, and any life member, honorary member, or patron; provided that only active members in good standing, life members, and distinguished service honorary members shall be entitled to vote.

ARTICLE III

Officers and Executive Committee

1. The officers of the Society shall be a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and a Librarian.

2. Only active members in good standing, life members, and distinguished service honorary members who have been in attendance at one of the two regular meetings preceding their nomination or election shall be eligible for such nomination or election one of the offices named in Paragraph 1; *except that* the Librarian shall be exempt from the requirement of attendance at one of the two previous meetings. Members who accept nomination and are elected to hold one of the offices of the Society are bound to perform their duties to the best of their ability and to advance the purposes and objectives of the Society.

3. Officers shall be elected and serve for a period of one year, or until the next regular or annual meeting, and shall (with the exception of the Secretary-Treasurer and the Librarian) be ineligible for re-election to the same office for a period of one year after the expiration of their terms of office.

4. The officers named in paragraph 1, the President of the preceding year, the chairman of any regional division established pursuant to the provisions of Article VI, and the chairman of any standing committees established in accordance with the By-laws adopted in accordance with Article V, shall constitute the Executive Committee. The Executive Committee is authorized to decide the policies of the Society, and to transact such business of the Society as may be necessary between regular or annual meetings.

5. In the event of the cancellation of a regular or annual meeting, the officers enumerated in paragraph 1 of this Article and the members of any standing or special committees established in accordance with the By-laws adopted in pursuance of Article V shall continue to serve until such time as a regular meeting can be scheduled at which new officers shall be elected and new committee members elected or appointed.

ARTICLE IV

Meetings and Voting

1. The Society shall meet once a year at a time and place to be decided upon by the membership at the preceding regular or annual meeting, or, in default of such decision by the membership, by the Executive Committee. Special meetings may be called by the President with the approval of the Executive Committee.

2. In the event of an emergency, the Executive Committee shall have the power to cancel a regular or annual meeting, or to change the place of an annual meeting; and in the event of such cancellation the Executive Committee shall have the power to schedule the next regular meeting.

3. A quorum at any meeting for the transaction of official business shall consist of at least twenty-five active members in good standing.

4. Decisions at meetings, including election of members, shall be by a majority of those present at any meeting; *except that* for a motion for amendment of By-laws adopted pursuant to Article V, a two-thirds majority shall be required; and *excepted further,* a unanimous vote shall be required for the election of honorary members.

ARTICLE V

Authorization for the Adoption of By-Laws

1. The Society is authorized to adopt and to amend subsequently as may be required, in accordance with the provisions of paragraph 4 of

Article IV, such By-laws as may be necessary for the conduct of the business of the Society.

2. By-laws adopted pursuant to the provisions of this Article must include, but shall not be limited to, the following:

(a) Set forth the amount of annual dues and special fees or assessments for the various classes of membership of the Society, and deal with other matters pertaining to the finances of the Society.

(b) Prescribe the duties of officers of the Society.

(c) Provide for the establishment of and specify the terms of reference or duties and method of selection (by Presidential appointment or by election) of such standing committees, other than the executive Committee, established in accordance with Paragraph 4 of Article III, and such sessional committees as may be necessary for the conduct of the business of the Society and the furtherance of its purposes and objectives. For the purposes of this subparagraph, (1) a standing committee is defined as one which is established permanently in the By-laws as a part of the basic organization of the Society; and (2) a sessional committee is defined as one constituted for the purpose of undertaking specific tasks at or in preparation for a regular or special meeting of the Society and is discharged upon submission of its report or completion of its business.

(d) Notwithstanding the provisions of subparagraph (c) of this paragraph, the President may appoint, or the Society, by adoption of an appropriate resolution, may direct the President to appoint special committees to undertake special assignments; and such authorization or appointments shall not require amendment of the By-laws, and such committees shall automatically be abolished on completion of their assignments or on the date of the next regular meeting, whichever occurs first.

(e) Provide authorization for such official publications of the Society as may be necessary in the furtherance of its purposes and objectives.

(f) Provide for the establishment and maintenance of any regional divisions of the Society established pursuant to the provisions of Article VI.

ARTICLE VI

Regional Divisions

1. A regional division of the Society may be established by the favorable action of the Society, pursuant to paragraph 4 of Article IV, upon a petition presented to it at any regular meeting by not less than twenty-five members of the Society in good standing resident in a particular geographic region.

2. Such regional division or divisions shall be organized in accordance with pertinent provisions of the By-laws adopted pursuant to Article V.

3. Each such regional division may adopt and amend from time to time its own By-laws, which shall conform to the provisions of this Constitution and By-laws of the Society adopted pursuant to Article V. The By-laws of regional divisions, after adoption and each amendment, shall be reviewed by the Executive Committee of the Society to insure conformance with the Constitution and By-laws of the Society. No By-laws of regional divisions or amendments thereof shall be considered effective until such review by the Executive Committee of the Society has been completed and the chairman of

the regional division has been notified in writing by the Secretary-Treasurer of the Society that such by-laws or amendments thereof are in conformity with the Constitution and By-laws of the Society.

4. Each regional division shall elect its officers, which shall consist of a chairman, vice-chairman and secretary. The chairman of any regional division shall be a member of the Executive Committee of the Society, and in his absence or inability to attend meetings of the Executive Committee the vice-chairman of that regional division may act in his stead. The secretary of any regional division of the Society shall serve as an assistant to the Secretary-Treasurer of the Society and shall carry out his duties in accordance with such procedures as may be determined from time to time by the Secretary-Treasurer of the Society.

5. All members of the Society who reside within a designated region in which a regional division of the Society may be established shall, upon election to membership and payment of dues prescribed in the By-laws, be considered a member both of such regional division and of the Society as a whole. Qualifications for membership in regional divisions shall conform to qualifications for membership in the Society. Regional divisions may elect active and life members only. The other classes of membership set forth in Article IV shall be elected only by the Society.

6. The regional divisions may, with the approval of the Executive Committee of the Society, levy such special fees, in addition to the dues of regular members of the Society, as may be necessary to meet any expenses of the regional divisions which are not properly chargeable to the regular funds of the Society. All regular Society dues shall be paid only to the Secretary-Treasurer of the Society. Any special fees collected by the regional division shall be disbursed by the secretary of the regional division in accordance with the By-laws of such regional division and the authorization of its officers and members.

7. The Executive Committee may allot to any regional division, from time to time, such sums from the treasury of the Society as may be necessary to further through the regional division the purposes and objectives of the Society. Such allotted funds shall be disbursed by the secretary of the regional division in accordance with its By-laws and the decisions of its officers and membership.

ARTICLE VII

AMENDMENT OF CONSTITUTION

1. This Constitution, after adoption in accordance with the provisions of the existing Constitution and By-laws, shall supersede such previously adopted Constitution.

2. The Constitution may be amended upon recommendation of three-fourths of the Executive Committee which shall be circulated in writing of the membership at least 30 days prior to any regular meeting at which a

vote is to be taken, and upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

3. A petition for amendment of this Constitution signed by not less than 50 members in good standing, irrespective of any action relative thereto taken by the Executive Committee in pursuance of paragraph 2 of this Article, shall be circulated to the membership by the Secretary-Treasurer at least 30 days prior to a regular meeting, and such amendment shall become effective upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

BY-LAWS OF THE AMERICAN FISHERIES SOCIETY

Section 1.—Duties of the President

The President is responsible for the business and organization of the Society, shall make such appointments as are authorized in the By-laws, and shall exercise such other functions and responsibilities as may be determined from time to time by action of the Society or the Executive Committee. He shall preside at all meetings of the Society and at all meetings of the Executive Committee, of which he is chairman.

Section 2.—Duties of the Vice-Presidents

The First Vice-President shall assume the duties of the President during his absence or in case of his inability to act. The Second Vice-President shall assume the duties of the President during the absence of the President or the First Vice-President or in case of their inability to act. Upon designation by the President, the First Vice-President or the Second Vice-President shall preside at sessions at regular or special meetings.

Section 3.—Duties of the Secretary-Treasurer

The Secretary-Treasurer, in his capacity as Secretary, shall be responsible for maintaining the official records of the Society, shall conduct its official correspondence, promote its membership, and shall make arrangements for regular and special meetings of the Society, and for meetings of the Executive Committee. He shall serve as parliamentary advisor to the President and chairman of committees to insure that the business of the Society is conducted in accordance with the provisions of the Constitution and By-laws.

The Secretary-Treasurer, in his capacity as Treasurer, shall receive and collect all dues, fees, accounts receivable, and other income of the Society, shall have the custody of its funds, and shall pay all accounts payable and other claims which have been duly authorized and approved. He shall furnish a bond in the sum of $25,000, on surety, to be approved by the Executive

Committee, the premium for such bond to be paid by the Society. The Secretary-Treasurer shall present an annual report to the Society.

Section 4.—Duties of the Librarian

The Librarian shall have the custody of the library of the Society, including its archives and printed publications, and shall have charge of the sale of extra copies of its publications. He shall transmit promptly to the Secretary-Treasurer monies received from such sales.

Section 5.—Expenses of Officers

No elected officer or committee member of the Society shall receive any salary or other compensation for his services. Clerical and other necessary expenses of elected officers and committee members may be defrayed by the Society provided that it has, through action at a regular meeting, or by vote of the Executive Committee in the event of an emergency during the interval between regular meetings, authorized such disbursements in advance.

Section 6.—Official Publications

The minutes and proceedings of all regular and special meetings of the Society and of any regional division established pursuant to Articles VI of the Constitution, together with reports of officers and committees at such meetings, technical papers furnished by members and selected by the Editorial Board for publication, and the official membership list of the Society shall be published in an annual volume which shall be numbered in series with the preceding volumes and shall be entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY. Each member of the Society in good standing shall receive one copy of the publications issued; except that each official member shall receive three copies of the publications issued; and excepted further, that publications shall not be distributed to patrons and *ex officio* honorary members.

Section 7.—Presentation and Publications of Manuscripts

Only members in good standing may present papers, either by reading or by title, at annual meetings of the Society or submit them for publication by the Society; *except* that outstanding non-members invited by the President of the Society, or Secretary-Treasurer with the advice of the President, who present papers at any meeting shall be exempt from this requirement. No member may have listed on the program of any meeting of the Society or any regional division thereof, or present, or have published in any one volume of the TRANSACTIONS, more than two papers; and for purposes of this section joint authorship shall be considered in the same status as sole authorships.

Section 8.—Dues of Members

The dues of the various classes of members, payable to the Secretary-Treasurer of the Society, shall be as follows:

(a) Active members, $5 per annum.
(b) Life member, $75; payable, if desired, in two consecutive annual installments of $37.50 each.
(c) Library member, $5 per annum.
(d) Sustaining member, $10 per annum.
(e) Official member, $40 per annum.
(f) Patron, a single conrtibution of $250 or more.
(g) Honorary member, no dues.

All dues, fees, or other monies due the Society shall be paid in currency of the United States of America, or the equivalent in foreign currency at current rates of exchange in the United States of America.

Section 9.—Loss of Membership

Any member who fails to pay his dues for a period of more than one year shall be given written notice by the Secretary-Treasurer that his name will be removed from the membership list unless back dues are paid in full within 60 days from the date of such notice. Any member who has forfeited his membership may not be reelected as a member for a period of one year from date of forfeiture of his membership unless he has paid all back dues and has paid dues for one additional year in advance.

Section 10.—Committee on International Relations

The Committee on International Relations is a standing committee responsible for keeping the Society informed as to the work of foreign technical agencies, international organizations, meetings, conferences, negotiations, exchange of persons and information, and related international matters of interest to the Society, and shall recommend such action or participation by the Society as may be appropriate in the furtherance of the Society's purposes and objectives. It shall consider problems of legislation and implementation of international agreements relating to the interests, purposes and objectives of the Society. The Committee shall consist of seven members in good standing, who shall be named by the nominating committee and elected by the Society. The Committee shall report to the Society annually concerning its work.

Section 11.—Committee on National-State Relations

The Committee on National-State Relations is a standing committee which shall act as a coordinating and advisory board for the consideration of interstate and National-State fishery problems and programs in the United States of America. It shall also consider problems of administration of fishery resources, and Federal and State legislation and the implementation thereof in the fields of fishery conservation and management. The Committee shall consist of five members in good standing, at least one and no more than two of which shall be an officer or officers of the United States Government, who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, which report shall include such recommendations for action by the Society as are considered appropriate.

Section 12.—Editorial Board

The Editorial Board is a standing committee responsible for the editing and publication of the proceedings of meetings, including technical papers and other manuscripts, and for their publication in the name of the Society. The Board shall consist of not fewer than five members in good standing of proven technical and editorial abilities, each of whom shall serve at the discretion of the President. Each President, immediately upon his election shall appoint the members of the Editorial Board, and shall designate the chairman for the coming year. The chairman of the Board shall be known as the Editor; each other member shall be termed Managing Editor, Associate Editor, Assistant to the Editor, . . . or given such other titles as may describe appropriately his functions and duties. The Editor shall assign duties to other members of the Board, and may solicit assistance, from time to time, for temporary periods from other members of the Society. The Board is authorized to establish and issue such standards and instructions to the membership as may facilitate its work. The Board shall report to the Society annually concerning its work.

Section 13.—Committee on Hydrobiology and Fish Culture

The Committee on Hydrobiology and Fish Culture is a standing committee which shall maintain a continuous survey and appraisal of research and applied work in the fields of aquatic biology, physiology, limnology, and oceanography as related to fishery science, fish culture, and fishery management. It shall develop and encourage the standardization and improvement of techniques, procedures, nomenclature, and measurements. The Committee shall be composed of seven members in good standing who are recognized specialists in various phases of fishery science and practice, and who shall be named by the nominating committee and elected by the membership. The Committee report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 14.—Committee on Commercial Fisheries

The Committee on Commercial Fisheries is a standing committee responsible for promoting and improving fishery techniques and the utilization of fishery resources for food and by-products, for the development and recommendation of standards of quality and sanitation, for the development and recommendation of standardized procedures for the collection and analysis of fishery statistics, and for related activities. The Committee shall be composed of seven members in good standing who are recognized specialists or authorities in fishery economics, technology, or the fishery industries, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 15.—Committee on Names of Fishes

The Committee on Names of Fishes is a standing committee responsible for the establishment and maintenance of a check list of common and scientific names of fishes, with the objective of achieving uniformity and avoiding confusion in nomenclature. The Librarian shall be custodian of the master check list. The Committee, in the furtherance of its duties, shall coordinate its activities with those of other societies and organizations throughout the world. The Committee shall be composed of seven members named by the nominating committee and elected by the membership, such members to be outstanding specialists in the fields of systematic ichthyology and fishery biology. The Committee shall report to the Society annually concerning its work.

Section 16.—Membership Committee

The Membership Committee is a standing committee responsible for maintaining and increasing the membership of the Society. The Committee shall take such measures as it deems appropriate and effective to stimulate interest in the Society and to further its purposes and objectives by interesting qualified persons in membership. The committee shall consist of the First Vice-President, who shall be chairman, of the Second Vice-President who shall be vice-chairman, and nine other members in good standing who shall be appointed by the President within 30 days after his election. The Secretary-Treasurer shall be an *ex-officio* member. The Committee shall report to the Society annually concerning its work.

Section 17.—Program Committee

The Program Committee is a standing committee responsible for arrangement of the program at the regular meetings, consisting of technical sessions for the reading and discussion of original papers, symposia on important topics, and exhibits of interest to the Society. It is the duty of the Committee to insure that the programs at the regular meetings are of high quality and achieve balance among the various fields of interest and activity of the Society. The Committee may recommend to the President the issuance of invitations to outstanding non-members to present papers or addresses. The Committee shall consist of five members in good standing appointed by the President within 30 days after his election, who shall serve until the close of the next annual meeting.

Section 18.—Committee on Water Pollution

The Committee on Water Pollution is a standing Committee which shall keep the Society informed on major developments in the fields of research, abatement, and pertinent legislation concerning water pollution that relates to the fish and fisheries. The Committee shall maintain a continuous survey and appraisal of the research and applied work in the water pollution field, and shall report its findings annually to the Society. These reports shall include such recommendations for action by the Society as are considered appropriate. The Committee shall consist of seven members in good standing who shall be recognized specialists in the water pollution field, and familiar with pollution problems in the several regions of North America, who shall be named by the nominating committee and elected by the Society.

Section 19.—Sessional Committees

The President is authorized to appoint, from the members of the Society in good standing, prior to, or at the beginning of each regular meeting, such sessional committees as may be necessary for the conduct of the business of the Society and other authorized activities in conjunction therewith; including the following:

(a) Nominating Committee of five, which shall name a list of officers and members of Committees that are subject to election by the Society, which shall be presented to the members for action at a regular meeting. It is the duty of the Committee to insure that all persons named shall conform to the qualifications for the various offices and committee memberships set forth in the Constitution and By-laws. The right of any member to nominate a candidate for any office or committee membership from the floor during a regular meeting, or to second such nomination, is expressly reserved.

(b) Resolutions Committee of five, which shall draft and recommend to the Society for consideration and vote at a regular meeting such resolutions, including amendments of the By-laws, as may be considered prudent and necessary for the furtherance of the purposes and objectives of the Society and for the conduct of its business.

(c) Auditing Committee of three, which shall examine the accounts of the treasurer and report its findings to the Society, and shall consider the annual budget of the Society prepared by the Secretary-Treasurer with the advice of the Executive Committee, and make recommendations concerning it for the action of the membership.

(d) Time and Place Committee of five, which shall consider and recommend to the membership for action, the time and place for subsequent regular meetings, but not for more than two years in advance of the meeting at which the committee is appointed.

(e) Publicly Committee of three members, which shall draft, approve, and disseminate appropriate press notices and reports concerning the meetings of the Society and the proceedings thereat as may be appropriate and in furtherance of the purposes and objectives of the Society.

Section 20.—Order of Business

The order of business at regular meetings of the Society shall include, but not necessarily be limited to, the following:

1. Call to order by the President.
2. Address of the President on a timely subject of his choice.
3. Roll call of members (or determination that a quorum is present).
4. Action on nominations for membership.
5. Introduction of noteworthy guests and visitors.
6. Appointment of sessional committees by the President:
    a. Nominating Committee of five.
    b. Resolutions Committee of five.
    c. Auditing Committee of three.
    d. Time and Place Committee of five.
    e. Publicity Committee of three.
7. Report of the Secretary-Treasurer.
8. Report of the Librarian.
9. Reports of the Chairmen of Regional Divisions.
10. Reports of Standing Committees.
11. Reports of Special Committees.
12. Program of papers, symposia, and discussions.
13. Report of the Time and Place Committee.
14. Report of the Auditing Committee.
15. Report of the Resolutions Committee.
16. Report of the Nominating Committee.

17. Election of officers and members of such standing committees as are subject to election by the membership.
18. Installation of newly-elected officers.
19. Other business.
20. Adjournment.

Section 21.— Northeastern Division (a) In accordance with the provisions of Article VI of the Constitution there is established a Northeastern Division of the American Fisheries Society which consists of members in good standing from the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and the District of Columbia in the United States of America, and the Provinces of New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, and Quebec of the Dominion of Canada.

(b) The Chairman of the Northeastern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Northeastern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 22.— Southern Division (a) In accordance with the provisions of Article VI of the Constitution there is established a Southern Division of the American Fisheries Society which consists of members in good standing from the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and members residing in Cuba, Puerto Rico, the Virgin Islands, and other West Indian islands.

(b) The Chairman of the Southern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Southern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 23.— Western Division (a) In accordance with the provisions of Article VI of the Constitution, there is hereby established a Western Division of the American Fisheries Society, which consists of members in good standing from the states of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming and the Territories of Alaska and Hawaii of the United States of America; and from the Provinces of Alberta, British Columbia, and Saskatchewan of the Dominion of Canada.

(b) The Chairman of the Western Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Western Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 24.—North-Central Division

(a) In accordance with the provisions of Article VI of the Constitution, there is hereby established a North-Central Division of the American Fisheries Society, which consists of members in good standing from the states of Michigan, Ohio, Indiana, Wisconsin, Illinois, Iowa, Missouri, Minnesota, North Dakota, South Dakota, Nebraska, and Kansas of the United States of America and the Province of Manitoba of the Dominion of Canada.

(b) The Chairman of the North-Central Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the North-Central Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1957)

Please check each item below before the final typing of your manuscript and help reduce the costs of publication, save your Editorial Board much needless work, and avoid delay in the publication of the TRANSACTIONS.

The following instructions were not drawn up arbitrarily but were condensed from regulations contained in the best style manuals. Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscripts must be typewritten double-spaced,** including titles, headings, legends for tables and illustrations, and literature citations. Write manuscripts only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies or originals made with a worn-out ribbon will not be accepted.** Do not use thin paper; heavy bond is preferred.

3. **Margins** at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages must be numbered in consecutive order,** including tables and pages carrying legends to figures. Tables and legends of figures must be inserted near their place of reference in the text. Place your name on the upper right-hand corner of each sheet of manuscript and write your name in pencil on the back of all photographs and drawings.

5. **Illustrations.** Make a separate page of each figure legend and limit the number of figures to those absolutely necessary to clarify or supplement text. Only sharp, glossy photographs can be used. Photostats will not be accepted. All drawings, charts, and diagrams should be prepared in waterproof India ink on high-quality paper or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. *All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend.* The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, and charts, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1. Do not use asterisks or other symbols to call attention to footnotes to tables.

7. **The title** of the manuscript, together with the author's name, division, or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

TREATMENT OF DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. **Inspect papers** in the last volume of the TRANSACTIONS if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in one of the two following forms. "A similar reaction to light was reported by Doe (1932)." "This type of reaction appears to be common (Doe, 1932)." Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus: (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below, to be placed at end of paper.

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN
1939. Treatment of diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450-461.

List only bona fide publications under Literature Cited. Do not list personal communications, typewritten reports, or processed materials given only limited distribution but rather give the appropriate citations in text footnotes at point of reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the TRANSACTIONS have been found to be incomplete and inaccurate. Help us correct this situation

11. **Tables.** Every table except leader work must have a heading and must be typewritten on a separate page. In preparing tables please make certain that they are not too large to appear on a single printed page and that the arrangement conforms with the format of the TRANSACTIONS. *Improperly prepared tables lead to the return of many manuscripts.* Number tables consecutively with Arabic numerals (1, 2, 3, etc.). Spell all words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all

decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

12. **Capitals.** Capitalize words when used as a part of a proper name or of an identifying number or letter, or when referring to particular States, Governments, and organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, the State, the Province, the Republic, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Hoover Dam, Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 6.

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a. m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longtitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. INDIANA.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5 - Sept. 2 (but April - September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5 - September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. **Numerals.** Spell out *isolated* numbers less than 10, but treat alike all numbers in a series of connected groups. For example: The nets contained nine bluegills. The catch included 9 bluegills, 20 smallmouth bass, and 123 pumpkinseeds.

Use figures for enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone but use numeral if part of a hyphenated expression: one-half inch; ½-inch mesh). Examples: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p. m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; fish 2 years 6 months old; 2-year-old fish; June 29, 1936; January 1938; the 20th day of March; 1937-1938; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch bluegills; 120 6-inch bluegills.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five lake trout," but write "Two hundred fifty rock bass and 325 lake trout were shipped."

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentences: "This species is adapted to *cold water.*" "Ciscoes are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manufscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. **Papers which are too poorly written will be rejected.**

17. **Be definite in reference to species.** The full common name and the scientific name must be given for each species mentioned. Scientific names may be omitted from the title, if desirable, but must be given at first reference to the species in the text. Once given, scientific names need not be repeated. Follow the Society's official list of names. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "showed," "found," "gave," and "presented", are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives.* Please check your manuscript for this common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every *case.*" "*The mortality* was *high* in every *pond.*"

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. **Things to remember.** Well written papers are the product of careful thought and hard work. Usually they require repeated revisions that incorporate suggestions from discerning and honestly critical associates. Please make these revisions *before* submitting your manuscript.

Good writing is to a large extent a matter of good taste and good manners. Careless presentation and poor organization are rank discourtesy toward the readers.

Careless writing may save time but, once printed, a weak paper stands long as a discredit to its author.

20. **Abstract of paper.** Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board.

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